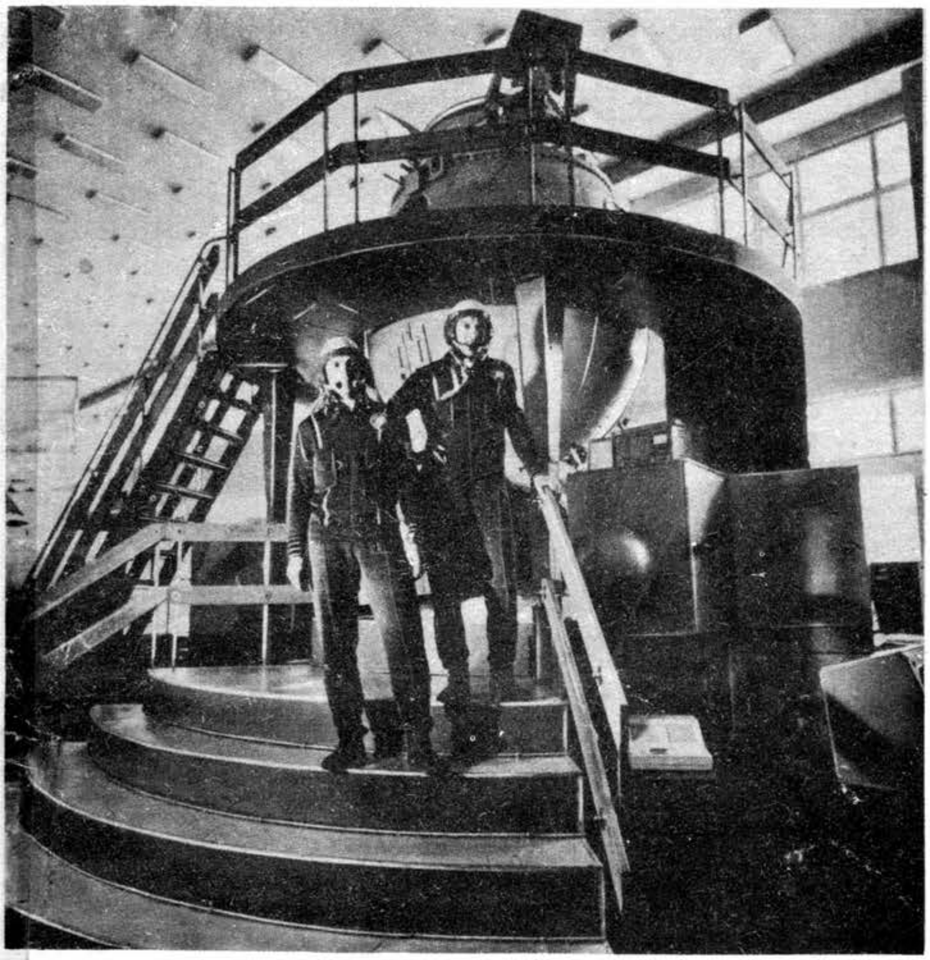
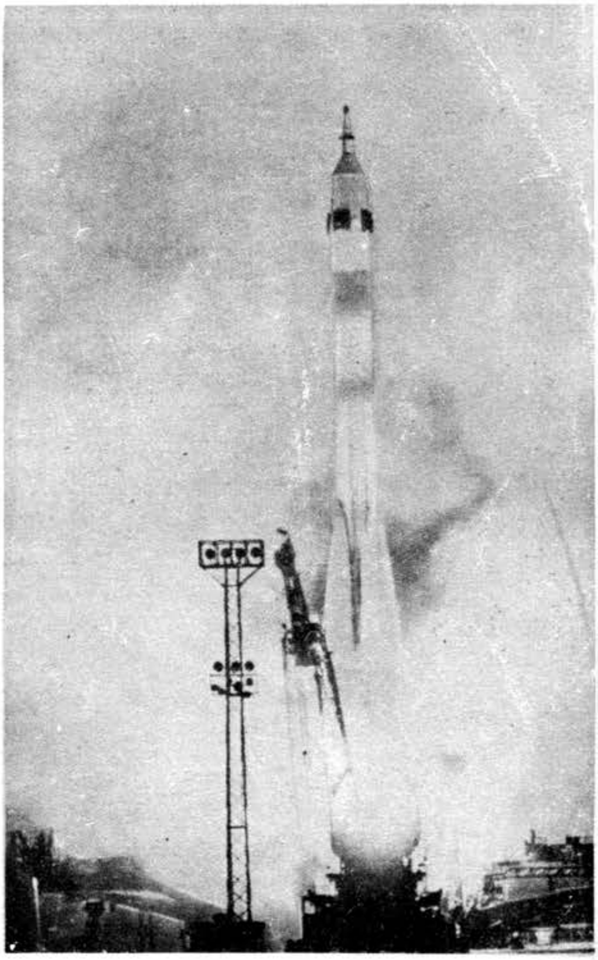
# SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-7
(спейсфлайт)
По подписке 1974 г.

Volume 16 No. 7 July 1974







Published by The British Interplanetary Society

*Editor:*
Kenneth W. Gatland, FRAS, FBIS

*Assistant Editor:*
L. J. Carter, ACIS, FBIS

**CONTENTS**



COVER

SUMMIT IN ORBIT. Active training of flight crews for the US/Soviet Apollo-Soyuz Projects starts at the Gagarin Space Centre near Moscow in July. The docking mission is scheduled to begin on 15 July 1975 with the launch of a Soyuz two-man spacecraft from the Tyuratam cosmodrome in central Asia, followed by the lift-off of a three-man Apollo CSM from the Kennedy Space Center in Florida. Apollo will be the active partner. The two crews are to visit each others' spacecraft after they have joined. Prime Apollo crew is Thomas P. Stafford; Donald K. (Deke) Slayton, and Vance D. Brand. Prime Soyuz crew is Alexei Leonov and Valeri Kubasov. Two more Soyuz craft will be on standby at Tyuratam with different crews. Pictures show training equipment at the Gagarin Space Centre and a typical Soyuz launch. *Top*, cosmonauts V. Dzhanibekov (left) and B. Andreyev on the steps of the Soyuz docking simulator; *right*, the lift-off of a Soyuz spacecraft at Tyuratam, and *below*, cosmonauts A. Filipchenko (foreground) and N. Rukavishnikov at a control console.

*Novosti Press Agency*

# SPACEFLIGHT

## A Publication of The British Interplanetary Society

VOLUME 16 NO. 7 JULY 1974 — *Published 15 June 1974*

MILESTONES

**April**

**3** Soviets launch Cosmos 638 from Tyuratam at 07.30 GMT into an orbit of 195 - 325 km inclined at 51.8 deg to equator. Signals received by Kettering Space Tracking group on frequency of 20.008 MHz are characteristic of Soyuz spacecraft. Re-entry module recovered on 13 April. Probably ASTP unmanned trial.

**11** Committee of Alternates representing member nations of ESRO/ELDO defer formation of European Space Agency (ESA) until mid-June pending agreement on choice of Director-General and because of the French elections following the death of President Pompidou. Sweden bids 3.0 per cent contribution to Marots programme (see table *Spaceflight* April 1974 p. 123).

**13** NASA launches Westar 1 domestic communications satellite for Western Union by Delta 101 from Kennedy Space Center. Geostationary satellite is capable of relaying 8 million words a second within the United States. Services include telegraph, telephone, digital data, facsimile and television (see page 274).

**14** Soviet and Indian space officials open talks in New Delhi which could lead to Indian research instruments being flown in Soviet space vehicles.

**14** Alexei Yeliseyev says docking mechanism tests for Soviet/US Apollo-Soyuz Test Project (ATSP) mission are highly satisfactory and problem of different life-support systems has been resolved. It remains to work out a common system for in-flight control.

**15** Majority of some 75 Soviet aerospace specialists arrive at Johnson Space Center, Houston, Texas, for three-week visit as part of Apollo-Soyuz Test Project and familiarization programme. Team includes Soviet ASTP technical director Professor Konstantin D. Bushuyev and cosmonauts Alexei A. Leonov and Valeri N. Kubasov (ASTP prime crew), Alexei S. Yeliseyev (Soviet flight director) and Valeri F. Bykovsky (ASTP training officer for Soviet ASTP flight crews. [Eight members of Soviet communications and tracking working group had previously arrived on 8 April to join nine Soviet engineers and technicians who had been at JSC since 11 January taking part in compatibility testing of radio and cable communication systems]. Latest discussions include problems of ground control, on-board documentation, ballistic calculations, safety, compatibility of radio systems, and life support systems.

**19** Controllers at NASA Ames Research Center command firing of Pioneer 11's thrusters at distance of 420 million miles to add velocity increment of 140 m.p.h. (230 km/hr) and divert spacecraft for close inspection of Jupiter's south polar region, with planned closest approach of 26,000 miles (42,000 km) on 2 December 1974. Subsequent 'sling-shot' will divert path to intercept Saturn in 1979.

**19** NASA re-schedules launch of ATS-F to 30 May.

**25** Col. William Pogue in New York reveals that a rich copper area in Nevada, discovered by the Skylab 3 astronauts, may have deposits worth possibly £900 million. If so this would represent about four-fifths of the entire cost of the Skylab programme.

**26** Committee of Alternates representing member nations of ESRO/ELDO receive 4.7 per cent bid from the Netherlands for participation in Marots programme; Denmark will not participate (see table *Spaceflight* April 1974 p. 123).

T 2

# MAPPING THE X-RAY SKY *

By Dr. Jeffrey A. Hoffman †

**In this issue we review some aspects of the 'New Astronomy' that have begun to emerge from the development of rocketry and astronautics. The review covers a wide spectrum of interest – from the latest results in X-ray astronomy to supernovae remnants, neutron stars, pulsars, black holes and quasars.**

### Introduction

Radio telescopes and orbiting observatories have become familiar enough in the news to dissuade most people from the notion that all astronomers look at the sky through telescopes on lonely hilltops. Astronomy has reached an epochal stage. All sources of information reaching us from space are studied – including the entire electromagnetic spectrum from radio to X-and $\gamma$-rays, neutrinos, meteorites, cosmic rays, and even gravity waves.

When Galileo first turned his telescope to the heavens, his visual resolution was enhanced to let him discover the moons of Jupiter, sunspots, and craters on the Moon. How different is the frustratingly myopic view of the sky available to radio astronomers of the 1950's and early 1960's and to X-ray astronomers of to-day. The former were limited in the clarity with which they could see the sky by diffraction of long radio waves collected by a finite diameter antenna. The latter suffer from the inability to focus short wavelength X-rays. Imagine an optical astronomer with 20/400 vision and no corrective lenses trying to construct a picture of the Universe! Fig. 1 makes this distinction by showing the loss of detail in the familiar Andromeda galaxy M31 as the angular resolution is progressively degraded.

In addition to wanting angular resolution to study the structure of celestial objects, non-optical astronomers need to be able to find the position of X-ray or radio objects with sufficient precision to allow their identification with optical counterparts. Then the traditional, powerful techniques of optical astronomy such as spectral analysis can be used to unravel the physics of these objects. Locating an X-ray object to within a degree still leaves hundreds of stars as possible counterparts, a near-hopeless task for identification.

Radio astronomers now possess multiantenna interferometer arrays capable of resolving small fractions of an arc-second, surpassing the arc-second resolution of current optical telescopes. X-ray astronomers will soon have focusing, grazing-incidence X-ray reflecting mirrors with resolution of arc-seconds for low-energy X-rays (below 3 keV).

Meanwhile, and in the case of high-energy X-rays for the foreseeable future, X-ray astronomers have been using a technique whose power to provide good angular resolution in observing celestial objects was first realised by radio astronomers in the pre-interferometry days: lunar occulations.

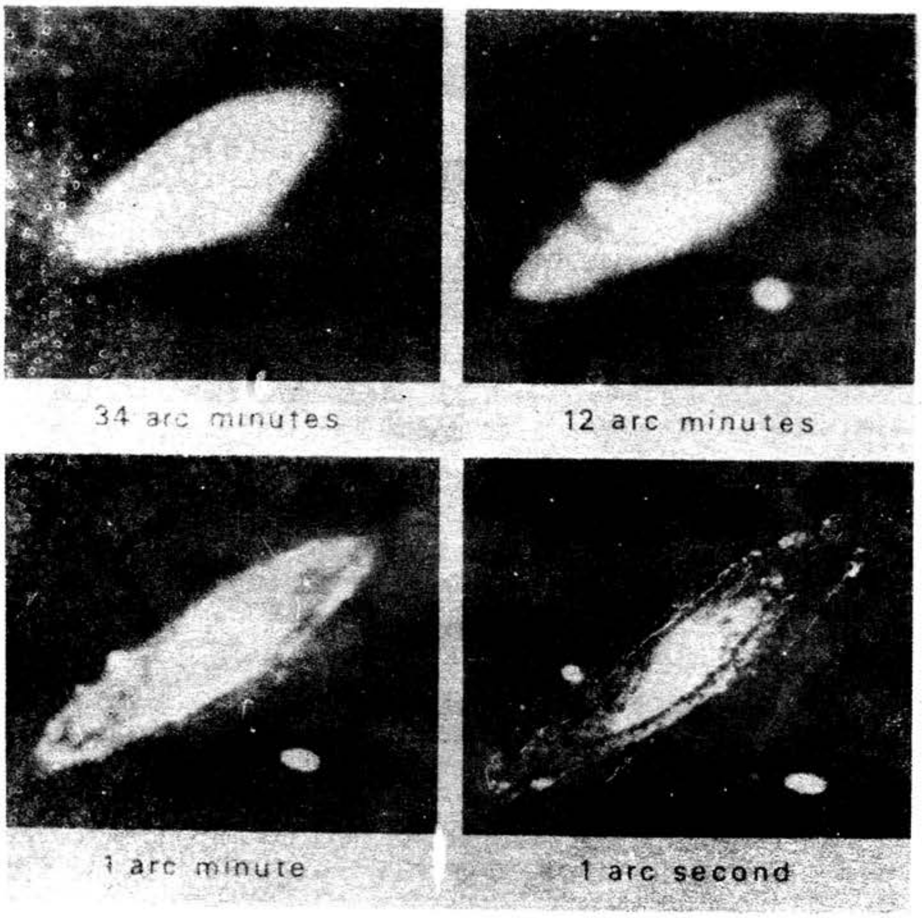
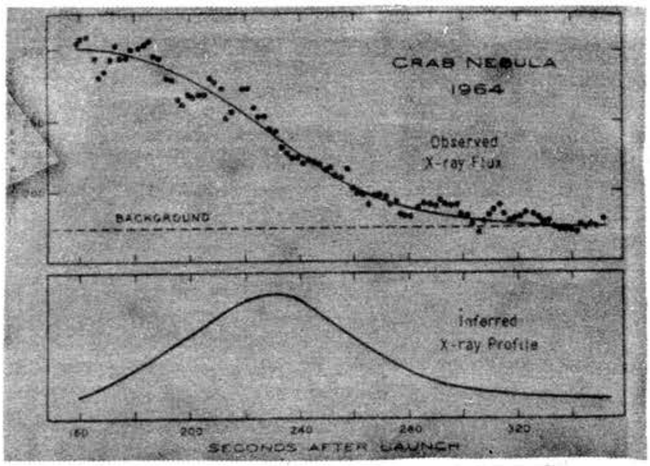



Fig. 1. The galaxy M31 in Andromeda, viewed with different angular resolutions. Currently, the best angular resolution achieved for celestial X-ray sources is about 1 arc minute.

*Space Science Reviews*



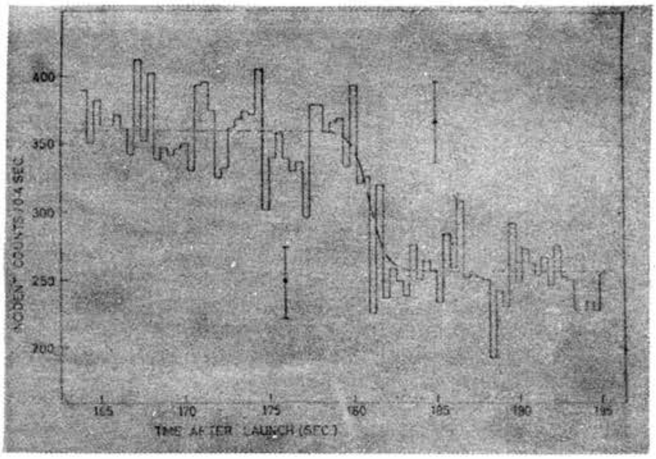




Fig. 2a. Intensity vs. time curve of the X-rays from a diffuse source (in this case, the Crab Nebula) being occulted by the Moon. The source disappears gradually. ("*Science*") Fig. 2b. A point source being occulted by the Moon. The source disappears all at once. ("*Nature*").

**Theory - When the Moon Eclipses a Star**

The Moon as seen from the Earth subtends ½° and follows a celestial path within 5° of the ecliptic, covering nearly 9% of the total area of the sky at some time. Accurately timed observations of the disappearance and reappearance of stars behind the Moon have refined our knowledge of the Moon's shape and orbit. This knowledge is now exact enough to allow a reversal of the technique: the position on the sky of the lunar limb can be predicted as seen from any given place at any given time.

When the Moon passes in front of an object, the object's radiation is blotted out – quickly if the object is small and slowly if it is large. The radiation from a large, uniformly bright object will disappear smoothly, while an uneven surface brightness results in an uneven disappearance. If an occultation is timed accurately, the position of the Moon's limb can be calculated to give the position of the occulted object. One disappearance or reappearance only gives a one-dimensional mapping, a "line of position", but several occultations together provide a full two-dimensional mapping. The resolution obtainable by this technique depends on the timing accuracy and on a knowledge of the detailed structure of the lunar limb (mountains and valleys). In principle, resolutions of better than an arc-second are possible.

**First X-ray Occultation - the Crab Nebula**

The first chance to use this technique came in the early days of X-ray Astronomy, when only two X-ray sources had been discovered. The X-ray source in Scorpius, the strongest in the sky, was not then identified with any optical or radio object. Another X-ray source was located in Taurus in the vicinity of the Crab Nebula, which was known to emit radio and optical radiation. The unusual nature of the Crab Nebula led most astrophysicists to assume that it was the source of the X-rays coming from Taurus. Consequently X-ray astronomers became interested in the lunar occultation of the Crab Nebula which was visible from the United States in September 1964.

Fortunately for our health, X-rays do not penetrate the atmosphere, but this burdens X-ray astronomers with the necessity of studying them from rockets and satellites, considerably complicating X-ray occultation observations. Whereas a radio astronomer can sit and wait for the Moon's occultation shadow to cross his telescope, an X-ray astronomer must ensure that his rocket-borne detector is above the atmosphere in the right place at the right time. A typical sounding rocket flight only lasts 5-6 minutes, and if the trajectory and time of launch are not properly chosen, the source will either be seen unocculted throughout the flight or will be completely hidden behind the Moon, missing the vital disappearance or reappearance.

In what was at the time a *tour de force* of rocketry, an X-ray detector built at the Naval Research Laboratory in Washington, D.C., successfully observed this occultation of the Crab Nebula. While the experiment confirmed that the X-rays did come from the Crab Nebula, the most anxiously awaited result was the measurement of the size of the X-ray emission region. Did the X-rays come from a point source or a large region? The existence of neutron stars and X-ray synchrotron radiation, fairly well established to-day, was under active debate then, and the answer had great implications for astrophysics. A diffuse source should disappear slowly as it passes behind the Moon (Fig. 2a) while a point source will disappear immediately (Fig. 2b). Figure 2a is, in fact, the actual record of the first Crab Nebula occultation – showing clearly that most of the X-rays come from a diffuse source, spread throughout the Nebula.

**Long Wait for the Galactic Center**

The results of the Crab occultation were received with excitement by astrophysicists, but no more rocket occulta-

* *Digest of a paper 'X-ray Source Mapping using Lunar Occultations Observed from Sounding Rockets', presented at the third meeting of Sounding Rockets and Experimental Results, organised by the British Interplanetary Society, University College, London, 27 September 1973.*

† *X-ray Astronomy Group, Physics Department, Leicester University.*

Fig. 3

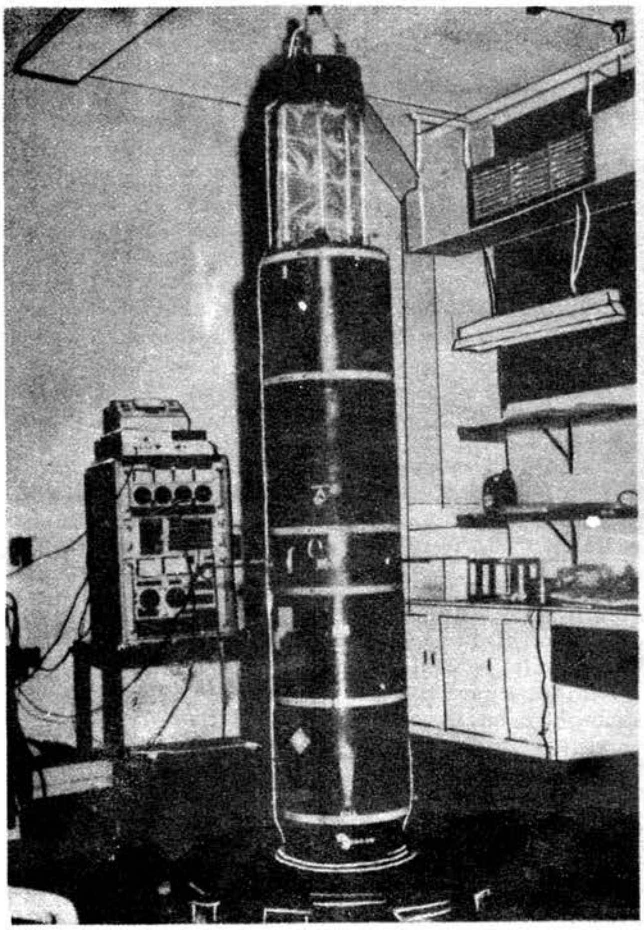
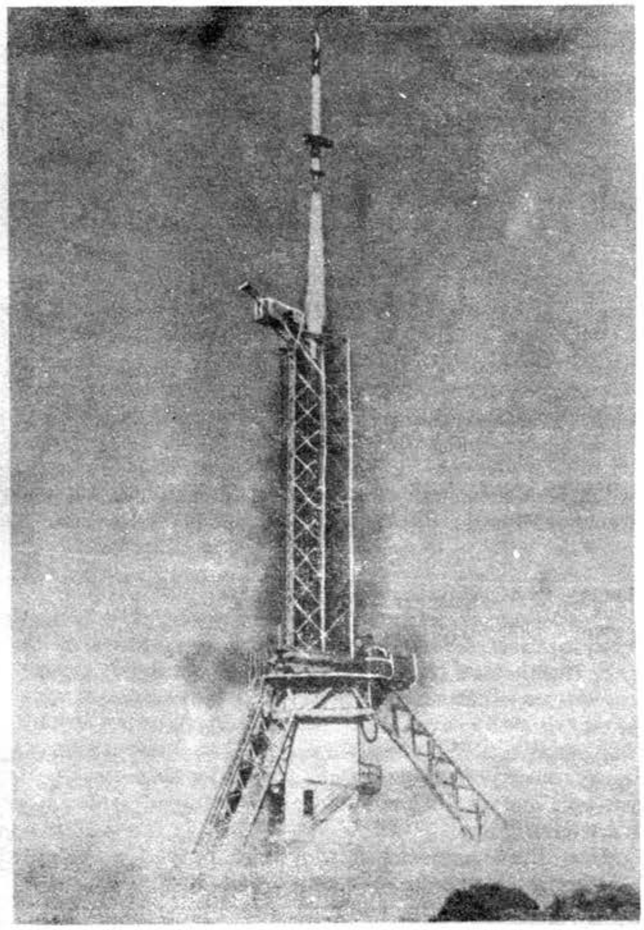


Fig. 4



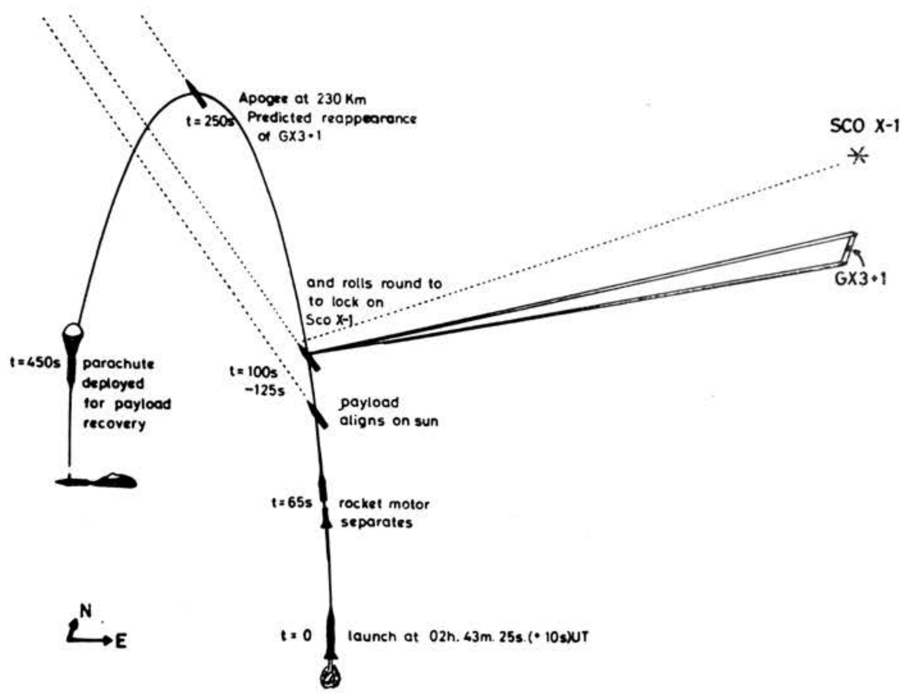



Fig. 3. X-ray detector (proportional counter array) to observe the lunar occultation of a strong X-ray source near the galactic center. Fig. 4. Launch of Skylark rocket with the experiment shown in Fig. 3 from Woomera. Fig. 5. Flight programme for the experiment in Figs. 3 and 4. The observation was successful and the payload recovered relatively intact from the desert.

Fig. 5

tion experiments were carried out for seven years for the reason that, although other X-ray sources were discovered, none had a sufficiently well-known position to ensure a reasonable chance of success for a sounding rocket experiment. The problem is fairly simple: one second of arc at the distance of the Moon subtends about 2 km. An average sounding rocket covers 250 km downrange, giving 2 arc-minute apparent motion of the Moon across the sky. The Moon's real motion during a 5-6 minute flight may add another 2 arc-minutes, making a total of 4 arc-minutes swept across in the sky. Unless the position of an X-ray source is known to this accuracy, the chance of its being in the relatively small region of the sky covered by the Moon during a rocket flight is too small to warrant an attempt to observe an occultation.

Positional accuracy of several arc minutes became possible in the late 1960's with the development of modulation collimators by several X-ray astronomy groups in Japan, the United States and England. With the possibility of further rocket shots to observe lunar occultations, The Nautical Almanac Office at RGO undertook to calculate when suitable occultations might occur. Luckily, the Moon was just beginning a series of occultations of the region of sky near the galactic centre, particularly rich in strong X-ray sources and of considerable astrophysical interest. Between 1971 and 1973, four sounding rocket experiments were flown from Woomera, Australia, by groups at Leicester University and Mullard Space Science Laboratory to observe occultations of GX3+1, GX5-1 and GX2+5.

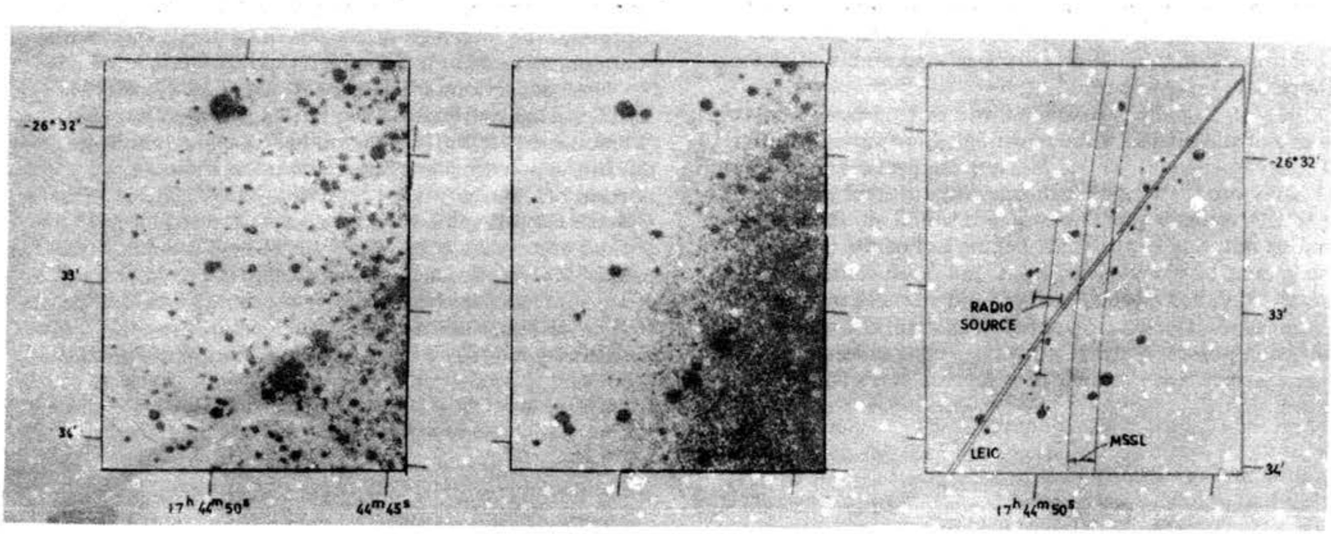
Occultations of GX3+1 were successfully observed in September and October, 1971, by both the Leicester and MSSL groups. Figs. 3-5 show the X-ray payload flown by Leicester, the launch, and the observation programme of the flight. Fig. 2b, the record of the Leicester observations, shows the relatively sudden disappearance of GX3+1, characteristic of a point source. The combined results of the two experiments gave a small area of the sky where GX3+1 might be located, shown in Fig. 6. The rich star density in the area shows the necessity of determining an X-ray object's position accurately if it is to be optically identified. Unfortunately there is no conspicuous optical object in the region shown, a disappointment perhaps not totally unexpected in view of the heavy absorption of light by dust in the galactic plane.

The remainder of the galactic centre occultation programme was less successful. The Leicester X-ray Astronomy group flew an experiment in December, 1972, to view the occultation of GX5-1, the brightest X-ray source near the galactic centre, similar in many ways to GX3+1. The round was launched at the correct time and the X-ray detector functioned perfectly throughout the flight, but the attitude control system of the Skylark rocket failed and GX5-1 was never seen.

In January, 1973, the M.S.S.L. group attempted to observe the occultation of GX2+5, a week galactic centre source. Its weak intensity had prevented modulation collimators from locating it with sufficient accuracy to permit an occultation shot. The M.S.S.L. experimenters attempted to locate GX2+5 more accurately using the recently launched ultraviolet and X-ray satellite Copernicus prior to the occultation experiment. Unfortunately, the position so derived was slightly in error, and GX2+5 was seen by the rocket experiment for the entire flight, the occultation being missed. No more rocket shots are currently planned for galactic centre source occultations.

### Second Time Around for the Crab

The Crab Nebula is undergoing another occultation cycle from March, 1974 to August, 1975. Ten years' development of astrophysical theory, supported by increasingly sophisticated experiments, has presented a far more complex picture of the Crab than was available in 1964. We know, for example that while most of the Crab's X-radiation is diffuse (as shown




A) INFRA-RED LIGHT. B) BLUE LIGHT. C) DIAGRAM OF OCCULTATION RESULTS AND POSSIBLE RADIO SOURCE, INFRA-RED SOURCES ALSO SHOWN.

Fig. 6. Sky map showing the position of the X-ray source GX 3 + 1 as determined from lunar occultations. The photographs were taken by W. Kunkel of Cerro Tololo Interamerican Observatory.

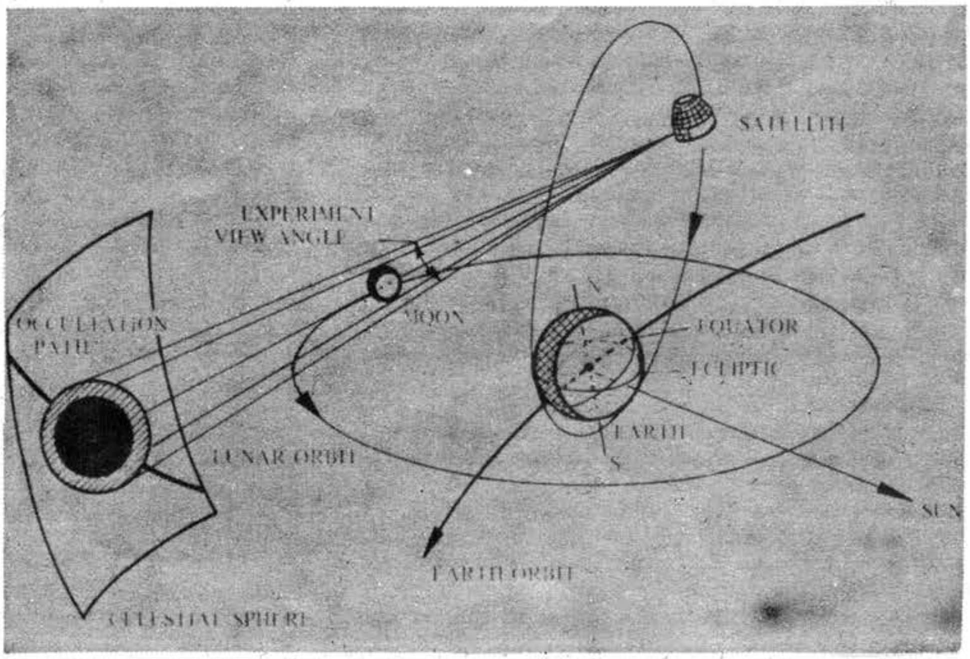



Fig. 7. Diagram of the future ESRO satellite EXOSAT, which will observe the lunar occultations of many X-ray sources due to its highly elliptical orbit.

by the 1964 occultation) a few percent is pulsed radiation coming from a point source, what is believed to be the neutron-star-pulsar. If the 1964 experiment had been only slightly more sensitive, it would have detected the point source, pulsed X-rays. (This would be visible as a sudden fall-off superimposed on the gradually decreasing curve seen in Fig. 2a). This time, ten years later, more sensitive rocket observations should provide detailed observations of the point source and diffuse radiation at X-ray energies from several hundred to several hundred thousand electron volts. Rocket flights to observe the Crab occultations in 1974-5 are being planned by groups at Leicester, Naval Research Laboratory, Columbia University and Lawrence Radiation Laboratory, Livermore.

One object of the experiments will be to determine how the size of the diffuse X-ray emitting region varies at different X-ray energies. Theories of energetic particle accleration and X-ray production mechanisms give different predictions for this. A resolution of the problem would aid the understanding not only of the Crab Nebula but of the origin of cosmic rays, of much of the X-ray and radio emission we see from the sky, and of the structure and strength of magnetic fields in space. Occultation experiments will also attempt to detect non-pulsed, thermal X-rays from the pulsar, providing the first direct measurement of a neutron star's surface temperature.

**Satellites and the Future**

For lunar occultation observations, as for most aspects of space astronomy, rockets, while valuable in their own right, have also served as developmental training grounds for techniques eventually embodied in satellite experiments. So while this article has concentrated on rockets, the use of satellites for observing lunar occultations should be mentioned.

A satellite has the advantage of being in orbit for a very long time and hence being able to observe many occultations. Moreover, every satellite occultation observation will include both the disappearance and the reappearance of the source. The Copernicus satellite, already mentioned, was used in a combined effort by Leicester, M.S.S.L. and R.G.O. to observe two occultations of GX5-1 in March and April, 1973. The position of the source was established to within several arc seconds, a particularly pleasing result in view of the dissapointment from the malfunction of the GX5-1 rocket experiment. As with GX3+1, no optical counterpart was found. Other occultations may be observable by Copernicus in the future, but Copernicus is limited to observing only those occultations which happen to cross its path. And, as with sounding rockets, only 9% of the sky is ever occulted.

These limitations are avoided by the ESR–planned HELOS (Highly Eccentric Lunar Occultation Satellite)* due for launch in 1979. HELOS will have a highly eccentric orbit out of the ecliptic plane and will see the Moon occult a large portion of the sky (Fig.7). Moreover an onboard motor will give the satellite periodic orbit corrections to ensure that desired objects are occulted. With HELOS in orbit, no more rockets will be launched to observe lunar occultations of X-ray sources. But the occultation technique will continue to provide high resolution mapping of the X-ray sky. For the first time, X-ray astronomers will see the sky with as much clarity as Galileo observed it in the optical part of the spectrum.

*In a later issue it is hoped to include a major feature on the Milky Way Galaxy. A report on the recent lecture to the Society by Professor Carl Sagan on the theme of Extra-Terrestrial Intelligence is in preparation. – Ed.*

---

** The name of this satellite was recently changed from HELOS to EXOSAT (European X-ray Observatory Satellite). Ed.*

# PULSARS, BLACK HOLES AND QUASARS



by Andrew C. Fabian

**Introduction**

Pulsars, quasars and black holes belong to the last decade or so of astronomy. Pulsars and quasars were discovered from observations and even now, theorists are uncertain as to the precise mechanisms underlying them, Black holes on the other hand have yet to be observed directly, although they have been known of in theory since 1798, when Laplace considered light being emitted from a very massive star. They had been mostly forgotten and ignored until the 1960's when, following the discoveries of radio galaxies, quasars and active galactic nuclei, theorists looked to gravitation as the energy source for the most powerful radiation emitters ever considered. Recent work in X-ray astronomy and other fields has heightened the interest in black holes until they have now almost become a household phrase.

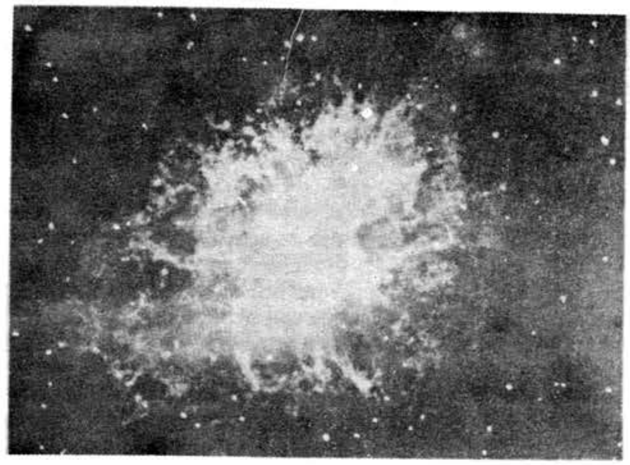
**Stellar Formation**

To begin our consideration of these topics, let us start with ordinary stars and what happens to them at the end of their lives. A star is probably formed when the gravitational forces within a cloud of gas cause it to collapse, since every particle of matter gravitationally attracts every other particle. If there are enough particles a very large force is developed. As the gas cloud collapses, the matter is heated up. We say that the gravitational energy of the matter is being converted into thermal energy, in a similar way to that in which sound and heat energy is released when a stone lands having been thrown off a cliff. For a mass of gas equal to that of the Sun, the energy liberated would be sufficient to keep the Sun's presently observed luminous output going for about 10 million years.

This is not the way in which stars keep up their energy output. When the core temperature has reached several millions of degrees, nuclear fusion takes place, and the star is stabilised for perhaps several tens of thousands of millions of years. In a sense, further collapse is prevented by the inflating effects of the energy trying to get out. As with all fuels, however, they are used up. The hydrogen is converted to helium, and then the helium to carbon and so on, perhaps, up to iron for massive stars. For a star such as the Sun, this will take $10^{10}$ years. Then the collapse will once again take over.

The Sun will not be able to support itself in the same way as the Earth stops itself from collapsing. Here the atoms remain fairly intact, but for the dying Sun, the pressures will force material into becoming degenerate. The Sun will be a white dwarf. Ordinary matter is composed mostly of space, or nothing. The constituent particles of atomic matter are less than one hundred thousandth of the size of an atom. Although there are few atoms as such inside a star, there is still a lot of space and with the terrifying pressures in collapse due to all the overlying matter, very high densities result. The Sun will end up being about one half of the size of the Earth.

There is a limit to the size of a white dwarf, however, and if a star is above about 2 solar masses, it will not collapse to form a white dwarf as the pressures are too great to be supported by electron degeneracy pressure. Stars have been known to explode and in the 1930's the idea of larger stars dying was tied up with the idea of explosion. For massive stars, the time spent on nuclear fusion is relatively short, and such high temperatures are reached that explosive conditions are created. The star may explode as a *supernova.* Simultaneously with the explosion, the core may implode, and the pressure of implosion may be sufficient to push the star through the white dwarf stage into a *neutron star.* These ideas were conceived soon after the neutron star was discovered only theoretically in 1932, by Landau in the USSR. Under such pressures, when solar mass is compacted into something about 10 Km in radius, the atomic nuclei are virtually adjacent. The electrons are pushed into the protons to form neutrons – the matter becomes neutron rich, thus the name neutron star. Star is perhaps the wrong word, except in mass terms, since a neutron star more closely resembles a planet in structure, having a liquid core and solid crust. Again its total mass cannot exceed more than two or three solar masses. If an object remains whose mass is more than two or so solar masses, it will probably collapse into a black hole.



The Crab Nebula

*Mt. Wilson and Palomar Observatories*

**Supernova Remnant**

A classic supernova remnant is the *Crab Nebula* in the constellation of Taurus. So called by Lord Rosse owing to its telescopic appearance, it was identified as a supernova remnant by Baade and Minkowski in 1942 as they considered that the *S* preceding star was the collapsed remnant. By 1963, the Crab had become quite a mystery, as X-ray observations had shown that it should die out in a few tens of years. However there is very convincing evidence that the supernova itself was observed by the Chinese in 1054 A.D., over 900 years ago.

Most emission from the Crab nebula is not thermal, i.e. not due to the nebula being hot, but due to *synchrotron radiation.* Electrons spiral around magnetic field lines at speeds close to that of light emitting such radiation as they do so. These electrons have to be continuously replenished but from where? The *S* preceding star? In 1967, F. Pacini put forward the idea that a highly magnetised rotating star may be the source of electrons.

Later, in 1967, the first *pulsars* were discovered by Bell, Hewish *et al.* in Cambridge (28 November). Regular flashes of radio radiation were emitted by a localised region of space. The regularity of these flashes or pulses was extremely precise suggesting that some form of mechanical clock was involved. Vibrating or rotating white dwarfs or neutron stars were the most likely candidates. As the pulses were studied, and further

pulsars were found, rotating neutron stars emerged as the location. Rotation was selected because vibration predicts a decrease in amplitudes as the pulsar loses its energy. Whereas this was not observed, there was an observed increase in pulse period agreeing with a spin down. Neutron stars give rotation periods over the observed pulsar period range of 33 ms to 3 or 4 sec.

In 1969, a pulsar was discovered in the Crab Nebula – the *S* preceding star. From its spin down, and taking a rotating neutron star as the pulsar, the loss of rotational energy ties up very well with the energy output of the whole Crab. This is the most convincing pointer to pulsars being neutron stars rotating, although there is now much circumstantial evidence as well.

Now over 100 pulsars have been observed and their distances range from 100 to over 2 Kpc. This suggests that our galaxy may contain over 100,000 'live' pulsars. Their distances are estimated from the later arrival of lower frequency pulses, owing to effects (electron dispersion) in the intervening interstellar medium.

Theories for the pulsations have been many, and argue about the exact location and mechanisms of the pulse formation. Gold pointed out in 1968 that a collapsed neutron star would have immensely strong magnetic fields (a million million times that of the Earth), and electric fields generated by the fast rotation would cause particles to be dragged from the surface and a large magnetosphere to build up. This would co-rotate with the neutron star out to a region where the tangential velocity approached that of light – the *speed of light cylinder*. It is quite possible for charged particles then to be moving at relativistic velocities here and this will give beaming owing to the aberration effect. Assymetry of the magnetic field with respect to the rotation axis can then be used to get pulses. However it must be stated that no one really knows where the pulses come from or how they are made. The radio emission must be coherent, but this is not necessary for the optical or X-ray. The observational data far outweigh the theoretical extent of our knowledge about pulsars. Detailed studies show intrinsic amplitude fluctuations, precursors, interpluses, marching subpulses, polarisation, etc. It may be some time before these are explained in any detail.

**Black Holes**

Black holes on the other hand are a case in which theory outweighs observation. Let us consider neutron stars in more detail. They have masses similar to the Sun but are only 10 Km.

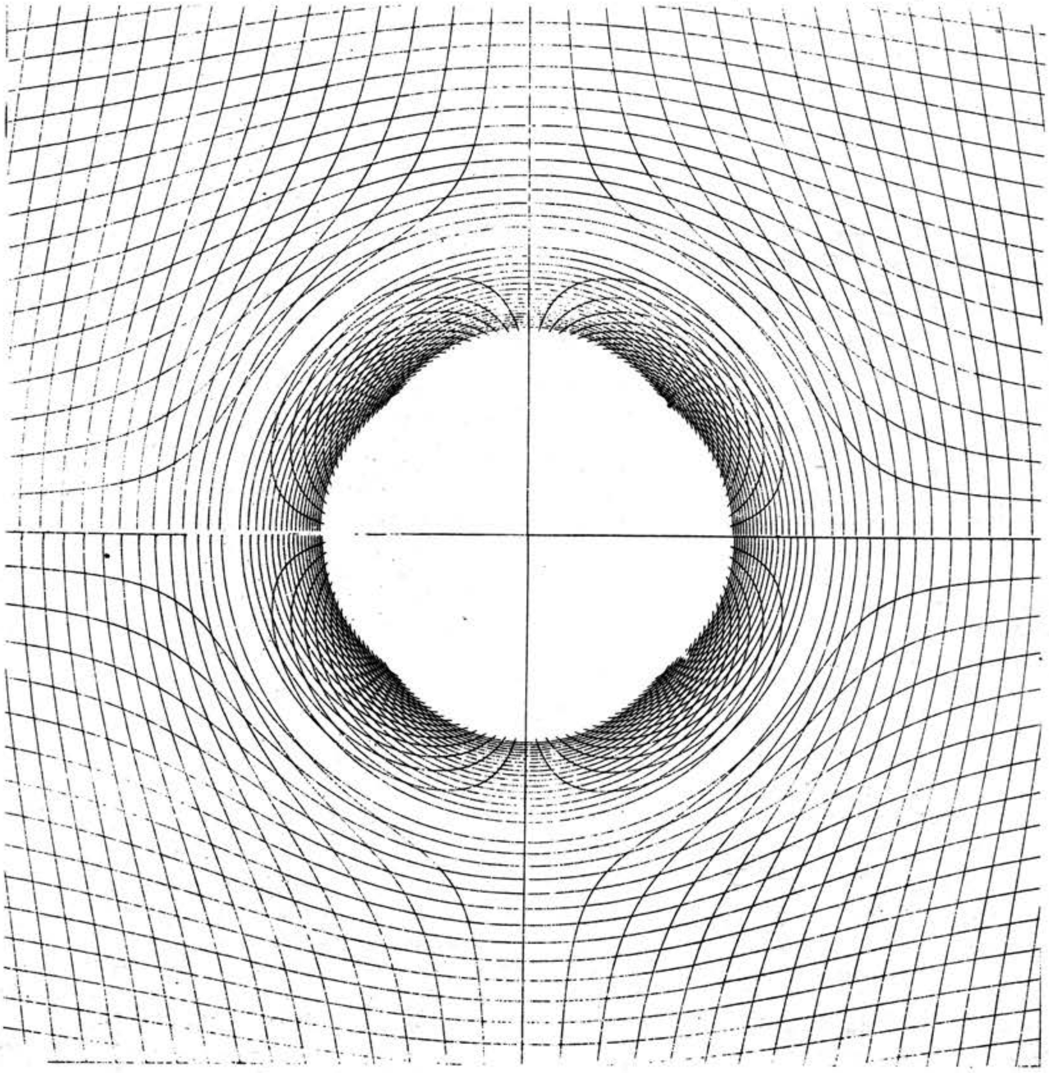


Fig. 1. This diagram, computed by Dr. Vincent Icke, displays the distortion produced by a black hole in front of a piece of rectilinear graph paper. The inner set of lines are produced by rays being deflected by an appreciable angle, e.g. those lines in the inner top left are the image of the lower right quadrant of graph paper. This inner set is incomplete, for the central disk should include rays which orbit the black hole, but it would be too intricate to display easily. The circular ring between the inner and outer sets of lines corresponds to $2R_S$.

or so in size. They are consequently very dense and have very high surface gravity, about one hundred thousand million times that of the Earth. A mountain on a neutron star would be about half an inch high, and in fact one does not metabolise enough energy in your whole life to climb even a quarter of it. A rocket would need to attain about $\sim 1/3$ the velocity of light in order to escape the neutron star. Relativistic effects would become important, with clocks running about 10% slower on the surface than elsewhere as observed away from the star. Light beams would be significantly bent. This *gravitational lens effect* would be noticeable to a hypothetical observer looking at the neutron star from nearby.

Now if we consider a body more massive than $2M_0$, it would collapse still further. The gravitational bending effect would become extreme as would the time slowing. Eventually, as it became more and more difficult for light to escape as it was caught in orbit around the star, no photons would escape at all as the body collapsed within its so-called Schwarzschild radius ($R_S$) which is $\sim$3Km for a solar mass. The time-slowing effect would also become extreme and in fact we would never see the star actually disappear. However it would appear black, as the star could only emit a finite amount of light in collapsing within $R_S$, and this is then released over an infinite amount of time. The region would go really black within a millisecond or so.

When this has happened, and even before if one is some distance away, there is no way in which you can influence or interact with the collapsed object. It really is a hole and black. You can of course fall in, but then you can *never* communicate with the outside world. What happens within is pure speculation, but infinite curvature and a *singularity* are predicted. From the outside, the black hole will appear as a black disc, with a severe distorting effect on the surrounding space. Well away from $R_S$, the gravitational pull will be the same as before the collapse, so it will only swallow a similar quantity of matter to that which came its way before. There is one difference of course, and that is as a star it could release some of this mass as matter or energy whereas it cannot do so now. It will just get bigger. It cannot be fragmented, or reduced in size. The least it can do is to stay the same size.

If the original star was rotating, this rotation will be enhanced on collapse, and the black hole will rotate. It then has a whirlpool effect and drags nearby things around with it. In fact within a certain distance you cannot remain stationary with respect to the distant stars but will orbit the black hole. This inner region is called the *ergosphere*. It is, however, possible to escape by firing rocket motors or the like. Some of the rotational energy can be extracted by various ingenious but perhaps technically implausible schemes.

Since a black hole is so small, it is pointless to search directly for it. Even if it was lying between us and a nearby star it would be difficult to see. Since $\sim$ 10% of all stars have masses $> 10M_\odot$, and present ideas suggest that some form of black hole ($4M_\odot$ or so) is left, then quite a lot of black holes must exist. However studies show that $< 10\%$ of the disc consists of black holes. The best way to seek them out is by observing radiation emitted by matter falling into a black hole before it actually gets to the $R_S$. Collision, turbulence, shock waves, etc., will heat this gas up until it emits X-rays. However a lone black hole will only accrete a very small amount of matter and will not in general be detectable. One in a close binary system in which mass transfer is taking place is a much better candidate, and in fact such a source of X-rays, Cygnus X-1 is currently considered to be the first observed black hole.

Black holes are important to modern physics as they present strong gravitational fields, and general relativity has only been tested in the weak fields of the solar environment. However, so far, no really plausible collapse procedure has been worked out except for very simple, controlled conditions. They may not exist at all, since relativity may break down in strong gravitational fields, or all stars or objects may explode before getting to the black hole stage. It is important to emphasise that it has nothing to do with the state of matter as a black hole of $10^9 M_\odot$ collapses through $R_S$ at the density of water, when we know nothing strange happens. However, it will be a very important step when one is found, since it represents potentially the most powerful source of energy in the Universe. They have been considered the powerhouses of the nuclei of galaxies and of our next stop, *quasars.*

**Quasars**

Quasars were discovered in the early 1960's and appeared as peculiar point like sources of light and radio emission, and with peculiar spectral lines. In 1963 M. Schmidt found that these lines were similar to ones in planetary nebulae, only greatly redshifted, indicating recession velocities of .8c or so. It has been known that the Universe is expanding since the 1920's and that the farther away an object lies, the greater is its redshift. Interpreting these redshifts in a cosmological way means that they are by far the most distant objects ever observed, and by far the most luminous. Variations in light output over months and years suggests that most of their emission originates in a compact region at most a few parsecs in size. We thus have an enormous amount of radiation being released from a very small region of space. Again the continuous emission is non-thermal. The emission lines probably originate in a surrounding diffuse gaseous region. Narrow absorption lines observed, not necessarily at the original redshift, may come from cooler clouds 'linelocked' to the quasar.

Selection effects in people's observations have been rife and at present true explanations of the quasars await clarification on the observational front. Are the quasars really at cosmological distances? If so they represent real evolutionary effects in our Universe. A few quasars lie in, and have the same redshift, as clusters of galaxies so at least for some the redshift must have a similar origin to that of glaxies. However, some quasars lie near objects that have very different redshifts.

How do we explain this? Is there another component to the redshift? It is hardly likely to be a 'local' velocity effect since an object would be disrupted. Gravitational redshifts have also been considered and rejected since it is very difficult to generate the high redshift in any plausible stable way. Pairs of quasars have very recently been observed, and some astronomers have now considered various classes of quasars.

The main energy source is probably linked to gravity somewhere, and massive black holes, rotating objects, etc., have been invoked. Similarities between quasars and the nuclei of galaxies have been pointed out and it is possible that they are just scaled-up versions of such nuclei.

Let us hope that the solution to some of these problems will come over the next decade. There again maybe they will hang around as unsolved problems for many years. Perhaps new physics is involved. We do not know, but astronomy has certainly become active in many ways since these problems came on the scene.

T 10

# 80,000 - YEAR VISITOR OBSERVED

By P. J. Parker

**Introduction**

Our rendezvous with the 80,000 year visitor began at exactly 17.30 on the 11 January 1974, when Dan-Air Comet-4B, G-APME, taxied out from the domestic pier of Manchester International Airport bound for a flight over the NW Atlantic Ocean. The purpose of the 2½ hour flight, specially organised by David McGee of Transolar Travel Limited (well-known to many BIS members for his space centre excursions), was to observe the Comet Kohoutek, 1973f, from a position well-above the restricting clouds.

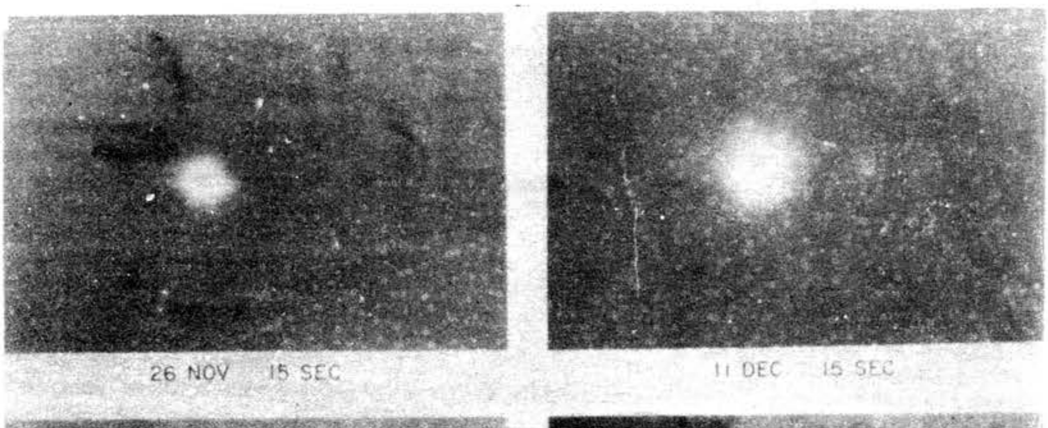
Originally billed as the 'Comet of the Century' by many leading astronomers, the comet had been somewhat of a disappointment during perihelion 'flyby', at 13 million miles from the Sun, on the 28 December 1973. Now, during early January 1974, it was very difficult to view with the naked eye from the United Kingdom.

Before perihelion, the comet had been an early morning object in the pre-dawn skies of December and, as such, was probably too early for even 'eager beaver' enthusiasts of astronomical phenomena. After perihelion, the comet switched to becoming an early evening January sky object but because of persistent cloud-cover over most of the UK it was almost impossible to sight the comet. The comet's failure to produce an extravagant head-and-tail made it an even more difficult object.

It was with pleasure, therefore, that I joined this special flight to ascend 33,000 ft above the NW Atlantic, high above the winter cloud cover and far removed from industrial smog and blazing city lights, to catch a 60-minute view of the Comet Kohoutek after it had swung around the Sun on its way back to the 'frozen' depths of our Solar System. It will be some 80,000 years before the comet once again will have the opportunity of vying for the title of 'Comet of the Century' – around AD 81,974!

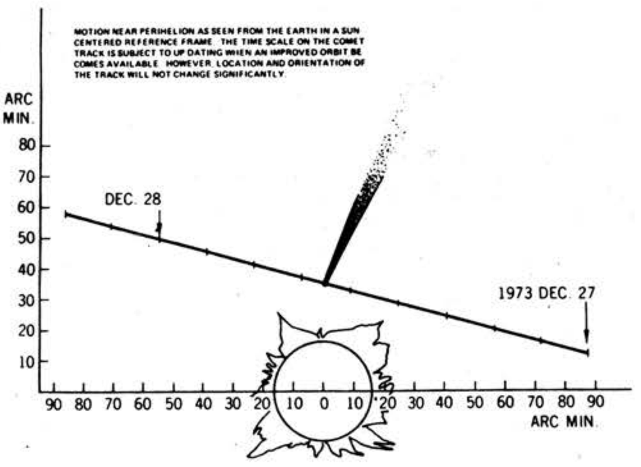
**Cometary Briefing**

Before the flight left Manchester Airport, a special briefing was presented to the participants, in the VIP Brabazon Suite, by Paul Doherty of the British Astronomical Associations Comet Section. Paul, a close neighbour of the writer, outlined facts and figures on the comet we were about to view. He explained that it had been discovered on the 7 March 1973 by Dr. Lubos Kohoutek, using the 32-in Schmidt telescope at Hamburg Observatory in West Germany. He also explained to the flight participants, about 75 people from many parts of the UK including many BIS members and amateur astronomers, that his own visual sightings of Comet Kohoutek had determined that its visual magnitude was mag. 5 on the 1 December and that this had become 4.5 mag, on 6 December. He explained that the comet's closest approach to the Earth would take place on 15 January 1974 – only 4 days after the special viewing flight, at a distance of 75 million miles. Paul also explained that this was the 10th brightest comet since Halley's Comet and that, on 10 January, it was about 18 times the Moon's diameter and had a 3.5 magnitude. At that time its tail appeared to be about



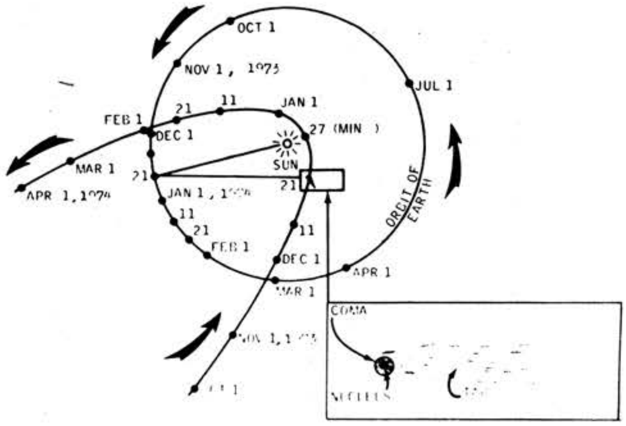

Kohoutek growth. Four far-ultraviolet views taken by the Skylab astronauts show the increase in the hydrogen halo surrounding the comet Kohoutek between 26 November and 25 December. The first three were made at a 15-sec. exposure, and the fourth (lower right) was taken during extra-vehicular activity at 2½-sec. exposure. All light but that in the hydrogen wavelength is filtered out.

*United States Information Service*




**This chart drawn before Kohoutek's arrival depicts the closest approach to the Sun between 27 and 28 December 1973. During this period the comet swung behind the Sun, as viewed from Earth.**

*National Aeronautics and Space Administration*




Orbit of the Comet Kohoutek.

*United States Information Service*

1.3 million miles. He asked for members of the flight to make notes and describe the colour of the central condensation in the comet nucleus for comparison with his own research notes. He pointed out that the comet's head was very bright, far brighter and easier to see than the tail.

**Origin of Comets**

The origin of comets is still a mystery. The most general theory is that they originate in a huge cloud, containing some 200,000 million comets, that lies somewhere between the extremity of our Solar System and the nearest stars. This theory, by Dutch astronomer Jan Oort, has prompted Fred Whipple, of the Smithsonian Institute, to theorize that maybe Uranus and Neptune were formed from comets.

As observed from ground-based telescopes and Earth-orbiting satellites, comets are a strange mixture of Earth-type elements and more exotic elements found in deep space. These include hydroxyl and cyanogen (in cometary heads) and carbon monoxide, carbon dioxide, hydroxyl and molecular nitrogen (in the tails). Comets usually have huge hydrogen clouds around them that increase in size as they approach the Sun. Many scientists feel, however, that comets contain ammonia, methane and water, in combinations that have survived since the formation of the Solar System.

In an effort to understand comets in more detail, the International Astronomical Union designated 18 days, between 26 November 1973 and 1 February 1974, for coordinated world observations. Additionally, NASA organised a massive programme called 'Operation Kohoutek', in an effort to throw new light on the physics and chemistry of comets.

This involved the Skylab 3 astronauts training their sophisticated ATM telescopes on the comet during their record 85 day mission aboard the space station; Mariner 10 Venus-Mercury spacecraft enroute measurements and observations, OSO 7 and OAO 3 (Copernicus) data, deep-space Pioneer spacecraft data and information from specially launched sounding rockets, balloons and jet aircraft.

With all these exciting scientific prospects, it was with enthusiasm that the privileged passengers of the Dan-Air Comet-4B prepared their telescopes, binoculars and cameras as the aircraft took off and left Manchester behind and headed out over the Irish Sea. Shortly after reaching 33,000 ft jubilant passengers, on the port side of the jet, shouted that they could see the comet! It appeared a good distance above the bright 'star' that was in fact, Jupiter. This sighting had many starboard side passengers racing for empty seats, near the windows. The flight crew, Mike Cooper and Captain Tudor, invited several people onto the flight deck to view this deep-space visitor through the cockpit windows. As the jet raced out to a point some 650 miles from Manchester, in about one hour, many sightings of the comet were reported. The best views came through with telescopes and binoculars, rather than the naked eye. The author was using a pair of Plus 20 x 50,3° field-of-view, binoculars kindly loaned from the UK distributors, Photopia International. These binoculars readily brought the dim comet into view in wondrous beauty unsurpassed by the naked eye. Though it was thought that conditions were entirely unsuitable for photography, from the moving platform of a jet with double window panes and backlighting from emergency aisle lights, I did, in fact, risk one photo with a Minolta SR T303 fitted with a MC Rokker fl.2/58 mm lens and using a fast film. On return I was quite surprised to find that the only photo taken did, in fact, clearly show the Kohoutek. This was due, in no small way, to the excellent operation of the Minolta camera, loaned from Photopia International.

The return flight did not afford much viewing time of the comet as the pilot had to use air-braking techniques to quickly reduce altitude, also, unexpected high altitude haze developed and ruined chances of an extra 30 minutes viewing time.

We returned to Manchester airport by the same route we had taken on the outward leg. This was via Northern Ireland

*[Concluded on page 280*

# STAR TREKKING: WHOSE SUN ARE YOU?



By A. T. Lawton

**Introduction**

The concept of life elsewhere in the Universe is now commonly accepted and the types of stars most likely to have life supporting planetary systems can now be identified.

The paper arises from work done for an artist friend who wished to portray and describe the conditions for Earth-like planets orbiting stars with different characteristics to the Sun, e.g., different colour, larger diameter, etc.

The paper details the parameters for such planets in chart form. Some of these parameters produce unusual results.

**Radiation Received by a Planet**

The radiation received by an orbiting planet is proportional to the following:

(1) The distance from the planet to the parent star.
(2) The size of the parent star.
(3) The temperature of the parent star.

These only account for the radiation receivable by the planet. The actual surface conditions on the planet are obviously sensitive to other items, e.g., rate of spin, atmospheric constituents (carbon dioxide, etc.) and angle of rotational axis.

**Radiation – Distance Relationship**

This is simply the well known inverse square law

$$R = \frac{a}{d^2} \quad \text{———} \quad [1]$$

where 'R' is received radiation
'd' is the distance parent star to planet
'a' is a constant and is the unit radiation of the parent star.

Thus a planet orbiting at twice the distance receives a quarter of the radiation.

**Size of Parent Star**

This is a direct square law since the radiating surface is a hemisphere (of area $\frac{\pi D^2}{2}$).

$$\text{Thus } R = \frac{a\pi D^2}{2} \quad \text{———} \quad [2]$$

where 'D' is the star diameter and all other parameters as Equn ——— [1]

combining [1] and [2] we get

$$R = \frac{a\pi D^2}{2d^2} \quad \text{———} \quad [3]$$

which has some interesting aspects discussed later for it is immediately apparent that two square laws cancel out.

**Surface Temperature of Parent Star**

This has a most dramatic effect for the radiation temperature relationship is the Stefan/Boltzmann law i.e.,

$$R = a\ T^4 \quad \text{———} \quad [4]$$

where T is surface temperature in degrees K (Kelvin).

The combined equations now give us

$$R = \frac{a\ T^4\ \pi\ D^2}{2\ d^2} \quad \text{———} \quad [5]$$

Thus a star of surface temperature of 12,000°K will have *16 times* the radiation of a Sun-like star of surface temperature 6,000°K, all other items being identical.

**Colour v. Temperature of Parent Star**

But how do we know the temperature which is clearly going to determine if we boil or freeze? Fortunately this is answered by Wien's law which states:

$$T = \frac{9.65 \times 10^{-12}}{w\ m}$$ where w m is the wavelength of the most intense radiation.

Now this is easy, since we can determine the wavelength in Angstrom Units (Å) by measuring the colour as in Table 1.

Table 1.

| Colour | Red | Orange | Yellow | Green | Blue | Violet |
|---|---|---|---|---|---|---|
| Wavelength Å | 6900 | 6100 | 5900 | 5600 | 4800 | 4000 |

The wavelengths quoted are the approximate centre bands. By measuring the wavelength (colour) of the most intense radiation we can determine the surface temperature of the star. By measuring the *total* radiation from the star we can calculate its diameter and this, in fact, is how star diameters, etc., are determined.

**Temperature vs Mass**

If we are interested in calculating the orbit for our 'Earth like Planet' then in addition to distance from the star, we must also know the mass of the parent star, since this determines the gravitational field in which the planet will orbit.

$$\text{i.e.,} \quad G = \frac{M + m}{d^2} \quad \text{———} \quad [6]$$

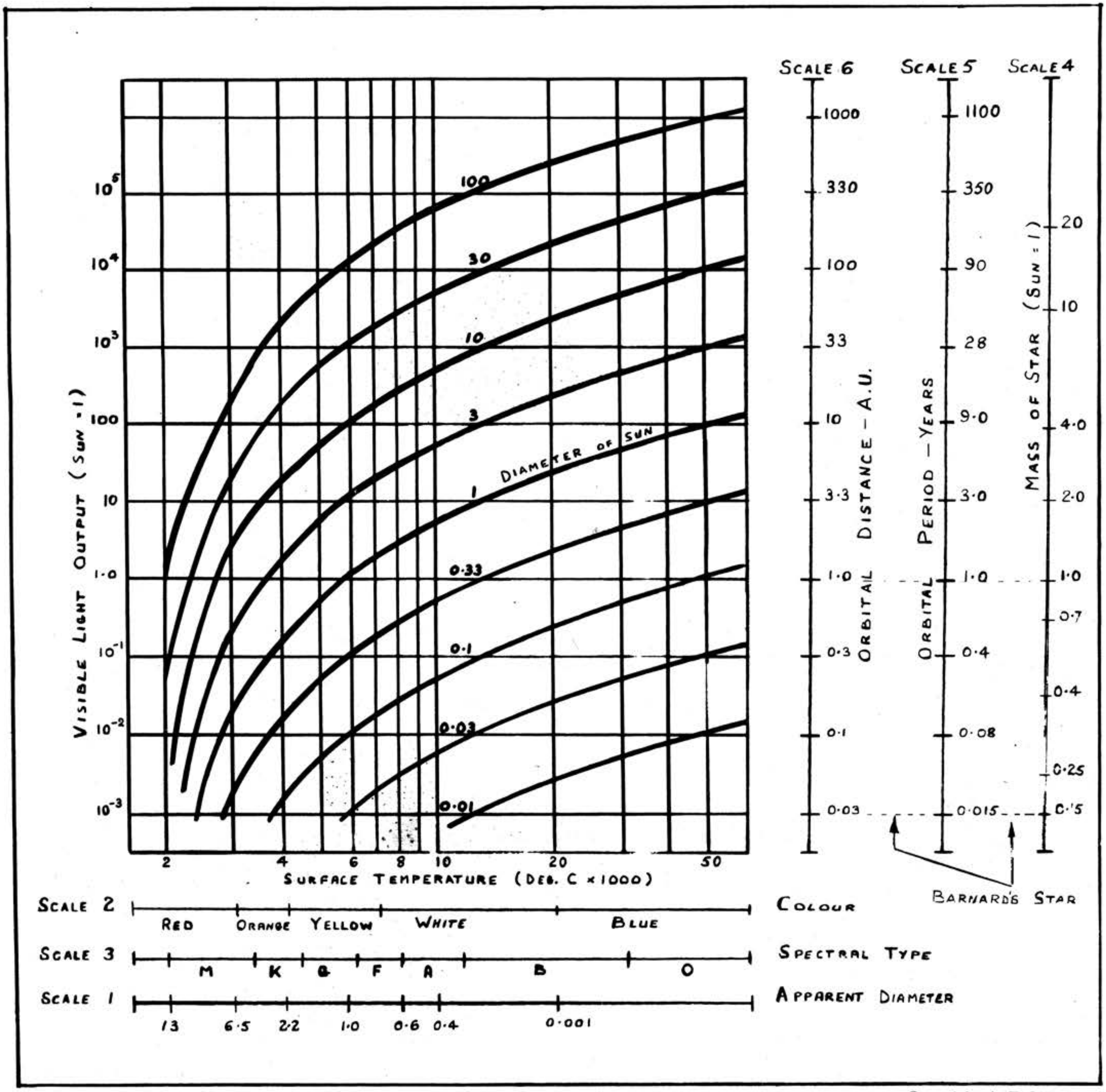
where M = mass of parent star.
m = mass of planet
G = gravitational force

Since gravitational force is directly proportional to the mass of the parent, and the orbital time is directly proportional to this force, then for a given distance we can say

$$O = k\frac{(M + m)}{d^2}$$ where O = orbital time
K = arbitrary constant

The 'arbitrary constant' is derived from Kepler's Third Law where the cube of the mean distance equals the square of the orbital time. Thus, if the Sun had twice its present mass, the Earth would move into top gear and screech around at 36 miles per second with a year of 182.5 days! It would also have a red hot surface not very 'Earth like' at all and in many respects resembling Mercury.

So how can we calculate the mass of a lonely star? The blunt answer is we cannot! Sir Arthur Eddington produced




Universal Star Chart. *Copyright A. T. Lawton*

the mass luminosity relationship which states that the radiation or brightness is proportional to the 3.5 power of the mass, i.e.,

$$B = M^{3.5} \quad \text{where } M = \text{mass}$$

$$\text{or } M = \sqrt[3.5]{B} \quad B = \text{brilliance}$$

Before the 'purists' start shouting, I am well aware that there are obvious exceptions but these are very unusual stars, and it is most unlikely that they have Earth-like planets.

Eddington himself always pointed out that it was an empirical relationship, assuming a perfect gas (or mixture of gases). A more precise determination of the relationship is the subject of much present measurement of metal ratios etc., in various stars. But for my artist friend's needs we may assume that Eddington's relationship holds for all Main Sequence stars.

The term 'for stars alone' is deliberate for if the star is a member of a binary system then the total system mass and

Table 2. Orbital Elements for Possible Earth-like Planets Associated with Stars of Various Masses.

| Star Mass | Star Brightness | Orbital Distance For Earth Type Planets | | Orbit Times For Earth Type Planets | |
|---|---|---|---|---|---|
| Sun = 1 | Sun = 1 | Miles x $10^6$ | A.U. | Days | Years |
| 0.15 | 0.001 | 3.1 | 0.033 | 4.6 | 0.012 |
| 0.2 | 0.0036 | 5.6 | 0.06 | 8.4 | 0.023 |
| 0.3 | 0.015 | 11.4 | 0.13 | 16.4 | 0.045 |
| 0.4 | 0.04 | 18.6 | 0.20 | 81 | 0.222 |
| 0.5 | 0.1 | 28.5 | 0.31 | 175 | 0.48 |
| 0.7 | 0.29 | 50 | 0.54 | 290 | 0.8 |
| 1.0 | 1.0 | 93 | 1.0 | 365 | 1.0 |
| 2.0 | 11.31 | 311 | 3.36 | 1095 | 3.0 |
| 3.0 | 45.7 | 630 | 6.76 | 2140 | 5.86 |
| 4.0 | 128 | 1050 | 11.6 | 3610 | 9.9 |
| 5.0 | 280 | 1555 | 16.7 | 5000 | 13.65 |
| 6.0 | 530 | 2140 | 23.0 | 6720 | 18.4 |
| 7.0 | 910 | 2800 | 30.1 | 8610 | 23.6 |
| 8.0 | 1450 | 3540 | 38.0 | 10720 | 29.4 |
| 9.0 | 2200 | 4360 | 47.0 | 18050 | 35.8 |
| 10.0 | 3150 | 5230 | 56.2 | 15300 | 42.0 |

the mass assignment to each member can be calculated. By taking a number of such binary systems and determining the mass/temperature/spectrum relationships for its members, it is possible to determine with reasonable accuracy a set of rules which can then be applied to single stars and the results agree satisfactorily with Eddington's formula.

A good example of this is *α Centauri 'A'*. It is a G type star identical in colour spectrum to the Sun, its distance is accurately known, and its total radiation has been accurately measured. It is slightly brighter than the Sun, has a slightly larger mass, and a slightly larger diameter. We can be sufficiently precise to say that the Sun has a diameter of 860,000 miles and *α Centaur 'A'* a diameter of 864,000 miles.

An Earth-like planet would therefore orbit at approximately 95 million miles, and the inhabitants would find it difficult to distinguish from Earth but for the presence of *α Centauri 'B'*. *α Centauri 'C' (Proxima)* can be neglected, it would not be seen in the skies of either 'A' or 'B' with the naked eye. For *α Centauri'B'* however, normal 'Earthlings' would notice some differences. The parent star would be orange and seem to be approximately twice the diameter of a normal Sun. The 'year' would be approximately 300 days and the distance from the star to planet would be approximately 60 million miles (0.64 AU).

Periodically the Earth planets of either star would experience 24 hour 'days' as the opposite number of this binary system moved to the appropriate position. Therefore, although the *mean* temperatures of Earthlike orbits would be acceptable, the actual temperature extremes would be more severe than is our present experience.

Nevertheless a 'twin Sun day' would be a glorious sight, and here the artist's brush replaces the slide rule.

**Orbits Galore – The Trek Chart.**

Therefore we can calculate orbits for any life-supporting planet in any likely star system from the basic equations:

(a) $R = \dfrac{a\ T^4 \pi\ D^2}{2\ d^2}$ for radiation received by a planet.

(b) $T = \dfrac{9.65 \times 10^{-12}}{w\ m}$ for a star's surface temperature from its colour.

(c) $O = \dfrac{k\ (M + m)}{d}$ for a planet's 'year'.

(d) $M = \sqrt[3.5]{B}$ for a star's mass from its brilliance.

Since all of this calculation is time wasting (especially when painting pictures to a deadline) a chart is much more convenient.

A basic form of such a chart has been known for years; it is the Hertzsprung-Russell diagram. By taking this diagram and plotting the characteristics of stars of constant diameter (brilliance VS surface temperature) it is possible to produce the figures of Table 2 and also to draw the 'Trek Chart' of Fig. 1. It is a multiple parameter diagram for it yields the following:

(a) The apparent diameter of the parent star as seen from the 'Earth-like planet'.
(b) The colour of the star and its class.
(c) The distance from planet to star.
(d) The orbital 'year' of the planet.
(e) The total radiation output of the star.
(f) The mass of the parent star.

This is irrespective of whether the star system is single.

**Apparent Diameter of Parent Stars as seen from 'Earth Planets'.**

Because of the cancellation of square laws mentioned in Equation [3], the apparent diameter of the parent star for a given temperature is *Always Constant*, no matter how bright the star may be. As an example the inhabitants of a *Capella* 'Earth' (*Capella* is 250 x as bright as the Sun) would see a star of the same size as the Sun but would orbit round it in a 'year' of approximately 12 Earth-years, and it would be at a mean distance of approximately 15.6 AU (1470 million miles).

On the other hand the inhabitants of a *Tau Ceti* 'Earth' would also see a star of the same size as the Sun, but they would orbit round it in a year of just over 6 months at a distance of 0.6 AU (56 million miles). A rich interstellar plutocrat could therefore indulge in a 6 year 'summer at *Capella*' and a 3 month 'winter at *Tau Ceti*' all inclusive tour!

**Effect of Temperature on Apparent Diameter as seen from 'Earth Planets'**

This is really drastic. Let us assume an Earth-like planet orbits Barnard's star. This has a visible light output of 0.001 x the Sun, and a surface temperature of 3000°C (Class M). Projecting upwards on the chart at 3000°C, we see the apparent diameter as 6.6 times that of the Sun (Scale 1), even though the real diameter is only 0.17 times the Sun.

Furthermore, if we project across at 0.001 from 'visible light output', the line intersects at a distance of 3.1 million miles (0.03 AU) on Scale 6 for distance from primary, and approximately 4 days on Scale 5 for the 'year'. What better

[Concluded on page 280

T 16

# A CORRELATION OF LONG-DELAY RADIO ECHOES AND THE MOON'S ORBIT

By George Sassoon

**Introduction**

Lunan [1] has proposed that long-delay radio echoes observed by Stormer [2], Van der Pol [3] and Hals [4] in the 1920's may be an attempt at communication by an alien space probe. Bracewell [7,8] has suggested that the communication may take the form of delayed echoes of Earth signals, variations in the delay time being used to attract attention and then present information. Lunan (op.cit.) presents an explanation of the Stormer/Van der Pol echo sequences in terms of star maps. Villard and co-workers [5,6] have collected and published a number of reports of long-delayed echoes received by amateurs.

The minimum signal delay observed by the early workers was 3 sec. Since this is approximately equal to the time taken for radio signals to travel to the Moon's orbit and back, it would be logical to look for evidence that the source of LDE was located at this distance. This is particularly of interest because there are two positions in the Moon's orbit, located about 60 degrees ahead of and behind the Moon, known as the Trojan positions or Lagrange equilaterals, where a body will be in stable equilibrium. That is to say, a space craft could be 'parked' at one of these positions and would remain there indefinitely without further fuel expenditure. There are also two positions of unstable equilibrium at a distance corresponding to an 8 sec. delay, and two stable positions (Earth-Sun equilaterals) at 17 min. delay distance.

The purpose of this paper is to present calculations of the positions of the Moon and its two Trojan positions in the sky of the observer, for each of 92 reports of the phenomenon being heard. These reports were selected from the collated publications of Hals, Van der Pol, and Villard. Selection was on the basis of accurately known time and date and also of location of the receiver. Reports without these data were discarded.

**Radio-wave propagation**

The majority of long-delay echo (LDE) reports are at frequencies in the range 7 to 30 MHz (wavelength 40 to 10 metres). At these wavelengths, ionospheric reflection occurs and signals can be propagated round the Earth with little attenuation under favourable conditions. However, the ionosphere is not a perfect reflector, and signals can penetrate it at high angles; alternatively, they can travel for some distance round the Earth by reflection, and then escape into space on reaching a region of weaker ionisation. The early Russian satellites transmitted on 20 and 40 MHz, and the 20 MHz signals were frequently heard when the devices were well below the horizon, and sometimes even when at the antipodes.

For this reason, one could expect that if the source of LDE was at a certain point in space, there would be some tendency for it to be heard more when that point was above the observer's horizon than when it was not. It would not be correct to expect it to be above the horizon for every report, even allowing for mistakes and hoaxes.

An estimate can be made of the transmitter power required at the distance of the Moon's orbit to produce signals of approximately the strength reported. No strength measurements appear to have been made, but from a knowledge of receiver performance and subjective strength reports one could estimate the signal strength at 1 microvolt in 75 ohms, or $1.33 \times 10^{-14}$ watts, although it is possible to that higher figures may apply for the comparatively crude receivers of the late 1920's.

The path loss between isotropic antennae in free space can be calculated from the well-known formula:–

loss (dB) = 37 + 20 log frequency (MHz)
+ 20 log distance (statute miles).

Taking 15 MHz and 240,000 miles, this gives 168 dB; increasing the assumed received power by this factor gives 866 watts, as the expected equivalent minimum transmitted signal power.

There will be some additional losses in the ionosphere, and also due to any intermediate reflections from the underside of the ionsophere or the Earth's surface. However, an interstellar probe with technology well in advance of our own could be expected to be equipped with a broadband directional antenna giving considerable gain over isotropic or 'all round' radiation. A power output of 800 or so watts is also a reasonable assumption, whether this is derived from solar panels and storage batteries or from an internal atomic power source.

**The Source Material**

Hals [4] gives a table summarising his own reports of LDE. This contains 27, of which 2 have no exact time given so are unusable. A further 5 are given in the text but not included in the table. To these we may add the report of Van der Pol, for the evening of 11 October 1929, making a total of 31.

Villard [5,6] gives two tables of amateur LDE reports. Of these the first (Feb. '70) yields 30 usable, the second (May '71) 31. All reports are used in the analysis for which a date and time are given.

This material gives a total of 92 reports, which are treated as 3 groups.

In this paper, the leading Trojan is defined as that which is ahead of the Moon in its orbit around the Earth, but which, due to Earth's faster rotation, rises and sets about 4 hours after the Moon. Likewise the Trailing Trojan is behind the Moon in its orbit but rises and sets about 4 hours before it.

**Analysis procedure**

The date and time of each report are reduced to GMT, and expressed as date and decimal of day, to four places. 'Leading date' and 'trailing date,' are found by adding and subtracting 4.7 days from these dates.

4.7 days is one-sixth of a tropical month, and represents the time-lag of the Trojan points ahead of and behind the Moon. One can assume with reasonable accuracy, that, for example, on 10 May at midnight GMT, the Right Ascension (R.A.) and declination (dec.) of the trailing Trojan will be the same as that of the Moon on May 5.3000 and for the leading Trojan the same as at May 14.7000. One therefore, looks up the Moon's RA and dec. in the Nautical Almanac for May 5.3, 10.0 and 14.7, and assigns these values to the trailing, the Moon, and the leading, as being correct at 10.0 May.

Sidereal time is also found for time of observation from the Almanac, and expressed in degrees for convenience of calculation. The latitude and longitude of the observer are also found from an atlas, and if the town cannot be found, a point near the centre of the State is assumed.

The local hour angle is then found from:

[Continued on page 260

THE HALS REPORTS.

| Sid. Time | Date/Time (GMT) | OBSERVER Lat | long | LEADING RA | Dec | LHA | El | MOON RA | Dec | LHA | El | TRAILING RA | Dec | LHA | El |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 056 | 1927 Apr 14.5938 | +60 | -11 | 230 | -15 | -163 | -43 | 178 | + 6 | -111 | - 5 | 122 | +23 | -55 | +37 |
| 063 | 1927 Apr 15.6090 | +60 | -11 | 243 | -19 | -169 | -48 | 189 | + 2 | -116 | -10 | 135 | +20 | -61 | +32 |
| 063 | 1927 Apr 17.6042 | +60 | -11 | 269 | -24 | 165 | -53 | 211 | - 8 | -137 | -29 | 156 | +15 | -82 | +17 |
| 048 | 1927 Jul 10.3333 | +60 | -11 | 301 | -23 | 118 | -34 | 232 | -16 | -173 | -46 | 176 | + 7 | -117 | -7 |
| 201 | 1927 Jul 12.7500 | +60 | -11 | 332 | -16 | -120 | -29 | 264 | -20 | - 52 | 0 | 206 | - 6 | +006 | +24 |
| 256 | 1928 Oct 11.6563 | +60 | -11 | 230 | -18 | 037 | + 6 | 177 | + 6 | 090 | + 5 | 115 | +25 | 152 | - 2 |
| 328 | 1928 Oct 11.8542 | +52 | - 5 | 233 | -18 | 100 | -20 | 180 | + 5 | 153 | -29 | 118 | +25 | 145 | - 7 |
| 280 | 1928 Oct 24.6875 | +60 | -11 | 040 | +13 | -109 | + 2 | 338 | -15 | - 47 | + 6 | 276 | -26 | 015 | + 3 |
| 025 | 1929 Feb 14.6667 | +60 | -11 | 091 | +26 | -055 | +40 | 027 | + 8 | 009 | +38 | 328 | -18 | 068 | - 5 |
| 026 | 1929 Feb 15.6667 | +60 | -11 | 107 | +26 | -070 | +32 | 037 | +14 | 000 | +44 | 340 | -14 | 057 | + 3 |
| 028 | 1929 Feb 18.6667 | +60 | -11 | 153 | +17 | -114 | + 3 | 080 | +25 | -041 | +45 | 016 | + 3 | 023 | +30 |
| 029 | 1929 Feb 19.6667 | +60 | -11 | 166 | +11 | -126 | - 7 | 096 | +26 | -056 | +39 | 028 | + 9 | 012 | +38 |
| 030 | 1929 Feb 20.6667 | +60 | -11 | 178 | + 5 | -137 | -17 | 112 | +26 | -071 | +32 | 041 | +15 | 000 | +45 |
| 031 | 1929 Feb 21.6667 | +60 | -11 | 189 | 0 | -147 | -25 | 128 | +24 | -086 | +23 | 055 | +20 | -013 | +49 |
| 036 | 1929 Feb 26.6667 | +60 | -11 | 248 | -20 | 159 | -47 | 193 | - 2 | -146 | -26 | 133 | +23 | -086 | +22 |
| 038 | 1929 Feb 28.6667 | +60 | -11 | 275 | -26 | 134 | -44 | 217 | -13 | -168 | -42 | 161 | +13 | -112 | + 1 |
| 327 | 1929 Apr 4.3750 | +60 | -11 | 008 | 0 | -030 | +26 | 311 | -23 | 027 | + 4 | 249 | -23 | 089 | -19 |
| 318 | 1929 Apr 9.3333 | +60 | -11 | 078 | +25 | -109 | +13 | 012 | + 2 | -043 | +23 | 314 | -22 | 015 | + 7 |
| 320 | 1929 Apr 11.3333 | +60 | -11 | 110 | +26 | -139 | + 2 | 039 | +14 | -068 | +23 | 339 | -14 | -008 | +16 |
| 095 | 1929 Apr 23.6771 | +60 | -11 | 265 | -26 | -159 | -53 | 209 | - 9 | -103 | -14 | 153 | +16 | -047 | +35 |
| 103 | 1929 May 16.6354 | +60 | -11 | 213 | -12 | -099 | -15 | 159 | +14 | -046 | +34 | 088 | +26 | 026 | +52 |
| 215 | 1929 May 23.9271 | +60 | -11 | 306 | -24 | -080 | -16 | 244 | -23 | -018 | + 6 | 190 | 0 | 036 | +24 |
| 116 | 1929 May 30.6354 | +60 | -11 | 035 | + 2 | 092 | + 1 | 331 | -18 | 155 | -45 | 270 | -26 | -143 | -48 |
| 260 | 1929 Oct 11.6667 | +60 | -11 | 358 | - 4 | -087 | - 2 | 301 | -25 | -030 | + 5 | 239 | -22 | 032 | + 4 |
| 251 | 1929 Oct 17.6250 | +60 | -11 | 077 | +26 | -175 | - 4 | 013 | + 2 | -112 | - 9 | 317 | -21 | -055 | - 2 |
| 280 | 1929 Oct 24.6875 | +60 | -11 | 179 | + 4 | 112 | - 7 | 115 | +26 | 175 | - 4 | 043 | +16 | -112 | + 3 |
| 105 | 1929 Oct 29.1875 | +60 | -11 | 234 | -20 | -118 | -31 | 177 | + 6 | -061 | +19 | 111 | +27 | +005 | +57 |
| 268 | 1929 Oct 31.6354 | +60 | -11 | 266 | -27 | +013 | + 2 | 206 | - 9 | 073 | + 1 | 148 | +18 | 131 | - 3 |
| 287 | 1929 Oct 31.6875 | +60 | -11 | 266 | -26 | 032 | 0 | 207 | - 9 | 091 | - 8 | 149 | +18 | 149 | - 8 |
| 283 | 1929 Nov 7.6563 | +60 | -11 | 353 | - 7 | -059 | + 9 | 296 | -26 | -002 | + 4 | 234 | -21 | 060 | - 4 |
| 294 | 1929 Nov 7.6875 | +60 | -11 | 354 | - 7 | -049 | +13 | 297 | -26 | 008 | + 4 | 235 | -21 | 070 | - 9 |

LHA = Sidereal Time - R.A. - Longitude (west).

and the elevation of the point above the oberver's horizon from:

elevation = arc sin (cos LHA cos lat. cos dec. + sin lat. sin dec.).

These calculations were performed for both Trojans and the Moon for each of the Hals reports, and for trailing Trojan only for the Villard reports.

The reasons why this was done were:

1. To save work.
2. The calculation is only necessary for one, since the three bodies' movements are correlated, and
3. Completion of the Hals reports gave a large correlation with the trailing Trojan.

**Preliminary results**

As mentioned above, the first table completed was that for the Hals reports. It was at once noticed that for the trailing Trojan, only two elevations out of 31 are below -10°. The average elevations were:

Leading: -11.2 Moon: +2.8 Trailing: +12.4

This highlighted the correlation between the bodies, for if the trailing Trojan is in the sky to the observer's south, generally speaking, the Moon will be near the horizon near the south-east, and the leading Trojan will be generally below it in the north-east. It is for this reason that the leading point is as significantly below the horizon as the trailing is above. If there were no correlation between any of the bodies and Hals's observations, all three should be near zero.

An extremely interesting feature of the Hals series is the group of reports from 14 to 28 Feb. 1929. This period coincides precisely with the half-month when the trailing point was above the horizon at 1600 GMT.

Looking at the average elevation figure of +12.4 degrees, one must ask 'What is the chance that this was a fortuitous result?' This can be estimated roughly as follows:

All but one of the observations were from Oslo at 60°N. The trailing point's declination varies sinusoidally about zero, so assume a mean declination of zero, i.e. postulate a 'mean trailing point' on the equator of the celestial sphere. From 60N, this point will have elevation varying sinusoidally between ±30° above the horizon about every 25 hours. At randomly-chosen points in time, this elevation will be either positive or negative, and the mean absolute value of elevation will be ± $(2/\pi)$ x 30 degrees, or ±19°.

Therefore consider a random process, repeated 31 times, in which 19 is either added or subtracted from an initial total zero. The finishing total is +12.4 x 31 or 385. For this to be the case, addition must have occurred 25 times, subtraction 6 times. It is as if a coin were tossed 31 times and came up heads 25 times. This will occur by chance only about once in 3400 attempts, which suggests a real connection between LDE and the trailing point rather than a chance one.

Moving on to the Villard reports, which were calculated for the trailing point only, mean elevations obtained were:

Villard Feb. '70: +8.8° Villard May '71: +10.7°

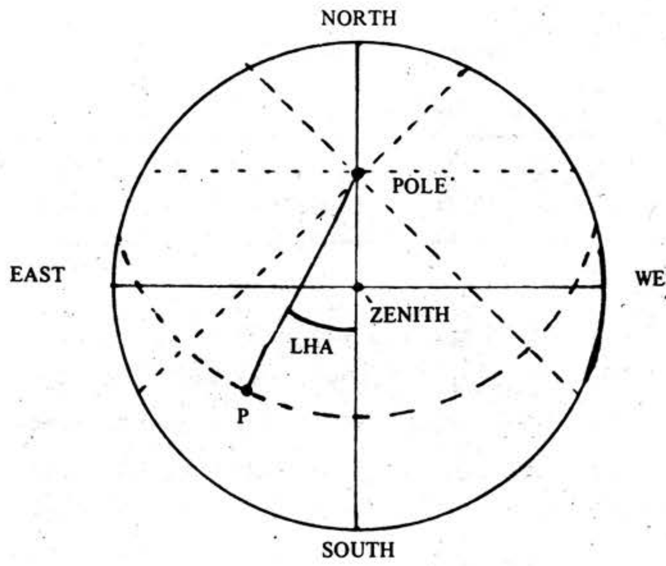



Fig. 1. Diagram illustrating relation of LHA, Azimuth, and Elevation.

Again, it is observed that the trailing point is consistently above the horizon, in both report groups. However, the reports in the groups originate from places at widely varying latitudes, so it is difficult to estimate the significance of them using the method adopted above for the Hals records. A different approach is needed to see if these results could have arisen by chance.

**Use of Local Hour Angle averaging**

Fig. 1 illustrates the view seen by an observer lying on his back at about lat.50°N. The outer circle represents the horizon, point P represents a star on the celestial equator (dotted circle), and the angle included by a great circle arc from P to the observer's meridian is the local hour angle of P.

Clearly, when P is zero, i.e. due south of the observer, its elevation in his sky is maximum, unless he happens to live at the North Pole when it is the same all the way round. This suggests that local hour angle can be used in addition to elevation, as regards a statistical analysis. Local hour angle is not so significant physically as elevation, but it is a lot easier to handle, statistically, since it varies linearly with time, rather than sinusoidally.

If there is a true connection between the trailing Trojan and LDE, one could expect LDE to occur generally with low values of trailing LHA, i.e., when it was near the observer's meridian.

Therefore, one can imagine the Moon and its Trojans as being attached to a gigantic roulette wheel in the sky, which rotates about once every 25 hours. For each report, a ball is popped into the slot nearest the observer's meridian. If the balls tend to concentrate near the Moon or one Trojan point the likelihood of it being a chance occurrence can be easily calculated.

Having comparatively few reports, the roulette wheel can be considered as having six slots, at LHA's 0°, ± 60°, ± 120°, 180° of trailing Trojan. To each slot we assign any observation where trailing LHA fell within ± 30° of that value. Results are shown in Table 1.

*[Continued on page 263*

VILLARD FEB. 70 REPORTS : Reports giving no date or time omitted.

| REPORTER | DATE/TIME (GMT) | LAT | LONG | SID. TIME | RA | TRAILING Dec | LHA | El |
|---|---|---|---|---|---|---|---|---|
| Barton, A.J. | 1960 May 21.9583 | +33 | -13 | 224 | 320 | -12 | -083 | - 1 |
| Birks, D.W. | 1968 Feb 3.7451 | +45 | +93 | 045 | 317 | -20 | -005 | +25 |
| Bock, A. | 1968 May 20.5208 | +42 | +72 | 066 | 283 | -28 | +071 | - 6 |
| Burr, A.F. | 1968 Oct 8.8333 | +32 | +107 | 318 | 345 | - 9 | -135 | -42 |
| Butler, J.A. | 1969 Feb 17.6146 | +35 | +120 | 009 | 273 | -29 | -024 | +22 |
| Carroll, R.E. | 1966 Jul 26.0958 | +42 | +84 | 338 | 166 | +11 | +088 | + 9 |
| Clark, V. | 1969 Jul 20.1993 | +36 | +80 | 010 | 126 | +23 | +164 | -29 |
| Clement, A.J.F. | 1968 Dec 18.8333 | +35 | +120 | 028 | 186 | - 3 | +081 | + 5 |
| Graf, C. | 1968 Jan 27.5938 | +30 | +99 | 340 | 212 | -13 | +030 | +38 |
| Grandgent | 1969 Aug 8.0090 | +41 | +73 | 320 | 017 | +10 | -131 | -37 |
| Hall, W.R. | 1969 May 2.9896 | +39 | +75 | 217 | 169 | + 6 | -027 | +39 |
| Hallcock, D. B. | 1961 Nov 20.2222 | +43 | +92 | 139 | 325 | -14 | +082 | - 4 |
| Hill, E.R. | 1941 Mar 1.6750 | +39 | +76 | 042 | 324 | -11 | +002 | +40 |
| Jones, D.L. | 1959 Mar 7.1944 | +42 | +88 | 235 | 255 | -18 | -108 | -25 |
| Kattan, G. | 1968 Dec 30.1667 | + 3 | +77 | 159 | 351 | - 7 | +90 | - 1 |
| McKinnon, J.C. | 1957 May 31.7083 | +12 | -162 | 144 | 032 | +14 | -086 | + 7 |
| Mattes, M.F. | 1960 Sep 21.0313 | +42 | +74 | 011 | 122 | +16 | +175 | -32 |
| Means, G.H. | 1932 Oct 16.7500 | +35 | +120 | 295 | 351 | - 3 | -176 | -58 |
| Miller, C.N. | 1969 Sep 22.0417 | +35 | +120 | 016 | 238 | -25 | +017 | +28 |
| Mix, D. | 1959 Jun 24.1875 | +42 | +71 | 340 | 247 | -17 | +022 | +28 |
| Myers, W.H. | 1969 Jan 21.6507 | +35 | +120 | 355 | 280 | -28 | -045 | +14 |
| Neal, J. | 1969 Jul 9.6896 | +40 | +83 | 176 | 354 | - 3 | +099 | - 8 |
| Nold, D.E. | 1969 Jul 14.1757 | +41 | +85 | 355 | 047 | +22 | -137 | -16 |
| Patterson, J.C. | 1967 Dec 2.5611 | +29 | +98 | 273 | 192 | - 4 | -017 | +53 |
| Prewitt, S.J. | 1960 Feb 3.9288 | +38 | +105 | 108 | 337 | - 7 | +026 | +39 |
| Pulitzer, S.M. | 1969 Apr 26.8750 | +30 | +90 | 214 | 093 | +29 | +031 | +63 |
| Simpson, A.A. | 1969 Feb 25.0542 | +50 | +97 | 174 | 016 | + 9 | +061 | +25 |
| Thompson, J.H. | 1958 Sep 7.1563 | +42 | +73 | 042 | 024 | +10 | -055 | +32 |
| Wellman, H.J. | 1969 Jul 13.5701 | +40 | +83 | 167 | 036 | +20 | +048 | +44 |
| Wiggins, B.A. | 1961 Dec 1.2083 | +35 | +120 | 145 | 114 | +19 | -089 | +11 |

VILLARD MAY '70 REPORTS : Reports giving no date or time omitted.

| REPORTER | DATE/TIME (GMT) | LAT | LONG | SID.TIME | RA | TRAILING Dec | LHA | El |
|---|---|---|---|---|---|---|---|---|
| Berman, L. | 1970 May 28.7500 | +35 | +120 | 156 | 282 | -27 | +114 | -34 |
| Bertolino,D. | 1969 Sep 22.9479 | +35 | +120 | 343 | 252 | -28 | -029 | +22 |
| Bieber, W. | 1969 Nov 3.0132 | +41 | + 74 | 047 | 081 | +28 | -108 | + 6 |
| Blair, B. | 1970 Mar 4.1875 | +35 | +120 | 342 | 225 | +22 | -003 | +33 |
| Bryant, J.A. | 1970 Jan 3.2917 | +38 | + 87 | 208 | 163 | + 8 | -043 | +41 |
| Childers, C. E. | 1969 Jul 23.8958 | +35 | +120 | 007 | 168 | + 5 | +079 | +12 |
| Connolly, P. | 1970 Mar 27.0070 | +45 | + 73 | 290 | 173 | + 2 | +044 | +32 |
| Cotton, L.S. | 1937 Apr 13.9514 | -32 | -133 | 184 | 350 | + 2 | -033 | +44 |
| Cummings, I.W. | 1970 Jan 2.6528 | +35 | +120 | 337 | 156 | +16 | +061 | +33 |
| Dietrich, T. | 1969 Jan 9.1250 | +41 | + 75 | 153 | 031 | + 7 | +047 | +37 |
| Dorson, D. | 1969 May 27.3646 | +25 | + 90 | 016 | 134 | +21 | +152 | -36 |
| Dougherty, W. | 1970 Sep 2.0000 | +27 | + 82 | 341 | 118 | +24 | +141 | -26 |
| Dreyer, H.W. | 1969 Nov 13.7326 | +24 | + 82 | 316 | 211 | -17 | +023 | +44 |
| Duff, W.A. | 1969 Aug 16.1181 | +41 | + 78 | 007 | 122 | +24 | +167 | -24 |
| Elsen, H.E. | 1970 Jul 27.2243 | +46 | +123 | 025 | 351 | - 2 | -089 | - 1 |
| Fisher, C. | 1970 Feb 21.1278 | +32 | + 84 | 197 | 095 | +28 | +018 | +74 |
| Fitz Patrick, T. | 1970 May 10.0257 | +18 | + 66 | 237 | 037 | +19 | +134 | -31 |
| Grady, M.E. | 1970 Feb 7.5042 | +43 | + 84 | 318 | 264 | +12 | -029 | +50 |
| Griggs,J. | 1938 Oct 19.2500 | +35 | +120 | 117 | 086 | +20 | -089 | +12 |
| Holowaty, M. | 1970 Jan 22.6944 | +40 | + 83 | 012 | 065 | +27 | -136 | -12 |
| Liming, J.S. | 1969 Dec 27.5694 | +51 | 0 | 301 | 080 | +28 | -139 | - 3 |
| Minter, M.K. | 1969 Nov 6.5972 | +51 | 0 | 261 | 128 | +23 | +132 | - 5 |
| Olsen, I. | 1970 May 20.8681 | -38 | + 59 | 191 | 175 | + 1 | -043 | +35 |
| Patrie, R.W. | 1969 Nov 3.6979 | +34 | + 84 | 294 | 091 | +29 | +120 | - 5 |
| Pendl, C.B. | 1961 Feb 20.5208 | +44 | + 90 | 338 | 335 | -10 | - 87 | - 5 |
| Pope, W.T. | 1970 Jan 21.0667 | +42 | + 74 | 144 | 044 | +21 | +027 | +60 |
| Seymour, G. C. | 1970 Jul 9.8889 | +53 | + 60 | 247 | 123 | +23 | +065 | +33 |
| Stange, D.A. | 1969 Dec 7.1667 | +43 | + 88 | 136 | 165 | + 7 | -117 | -15 |
| Stines, B. | 1970 Apr 15.1556 | +36 | +115 | 259 | 072 | +27 | +072 | +30 |
| Tillery, B. | 1970 Sep 7.1486 | +34 | +112 | 039 | 176 | 0 | +112 | -18 |
| Williams,K.W. | 1951 Apr 3.2708 | +35 | +120 | 258 | 269 | -28 | -131 | -48 |

TABLE 1.

| Report group: LHA range | Hals | Villard Feb, 1970 | Villard May 1971 | Total |
|---|---|---|---|---|
| -90/-150 | 4 | 4 | 5 | 13 |
| -30/-90 | 6 | 6 | 6 | 18 |
| +30/-30 | 10 | 8 | 6 | 24 |
| +90/+30 | 7 | 7 | 6 | 20 |
| +150/+90 | 3 | 2 | 6 | 11 |
| -150/+150 | 1 | 3 | 2 | 6 |

These figures are given graphically in Fig. 2. Clearly, there is a considerable bias towards the sector of the wheel centred on the trailing Tojan. If the wheel were unbiased, one could expect $92/6 = 15.3$ reports per $60^\circ$ sector, with a standard deviation of $((92 \times (1/6) \times (5/6))^{1/2} = 3.57$. The figure of 24 at the trailing Trojan's sector is thus 2.42 standard deviations high, the odds against this being a chance occurrence being about 100 to 1. If the slots are grouped in two threes, the three closest to the trailing point and the three furthest, the closest group predominates by 62 to 30. Here the deviation is 3.34 times standard, a very significant level.

An alternative approach is to perform a vector averaging operation on the LHA's. This is equivalent to starting from the centre of a circle, and drawing a line unit length in the direction of the first LHA, then from that point another line in the direction of the second LHA, and so on. If the LHA's are evenly distributed round the clock, the finishing point will not be far from the start; if not, the direction of the finishing point from the start gives the mean direction, and the distance is a measure of the extent to which the LHA's are in the same direction.

This can be done simply by summing the sines and cosines of the LHA's. The vector length is given by $((\Sigma \sin \text{LHA})^2 + (\Sigma \cos \text{LHA})^2)^{1/2}$, and the mean LHA by arc tan ($\Sigma \sin \text{LHA} / \Sigma \cos \text{LHA}$).

The results of this operation are as follows:

TABLE 2.

| Report group: | Hals | Villard Feb. 1970 | Villard May 1971 | All |
|---|---|---|---|---|
| $\Sigma$ sin LHA | +0.8050 | +1.1201 | +1.9327 | +3.8578 |
| $\Sigma$ cos LHA | +10.4260 | +7.0389 | +2.5664 | +20.0313 |
| Vector length | 10.4570 | 7.1275 | 3.2127 | 20.3994 |
| Mean LHA | +004° | +009° | +037° | +011° |
| No. reports | 31 | 30 | 31 | 92 |
| Std. deviation vector length | 4.373 | 4.302 | 4.373 | 7.533 |
| Vector/s.d. | 2.39 | 1.657 | 0.735 | 2.708 |

These results indicate that the mean local hour angle is a few degrees west of south. This could indicate a lag in time before LDE is noticed, although the number of reports is insufficient for the small angle to be significant. Standard deviation of vector length is calculated from $(\pi/2)(n/4)^{1/2}$, where n is no. of reports. This gives the vector length one would expect if the LHA's were truly random. As in the earlier analysis, the figures reveal a systematic tendency in the direction of the trailing Trojan.

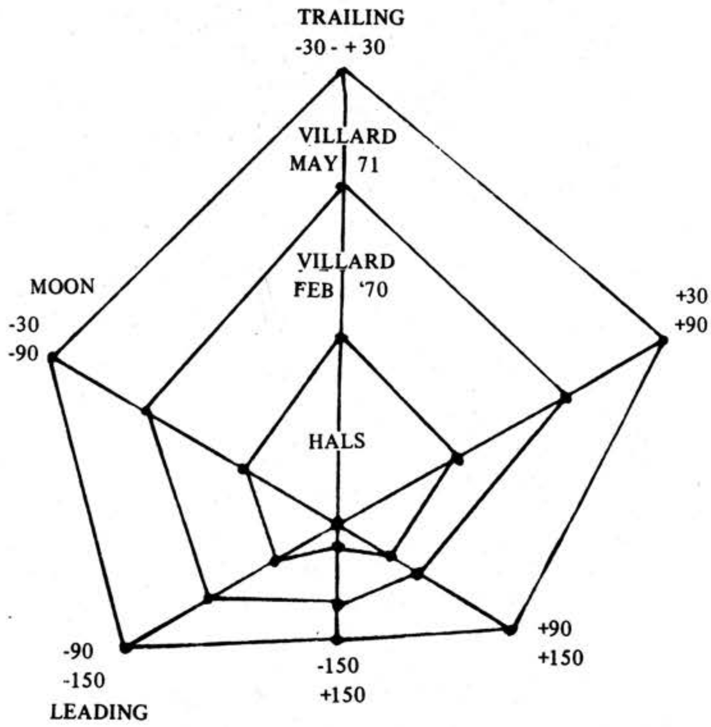



Fig. 2. Polygonal histogram showing bias of "Roulette Wheel" towards trailing Trojan (one report equals 0.1").

**Conclusion**

The analysis of 92 long-delay echo reports indicates a statistically-significant tendency for echoes to be heard when the trailing Moon-equilateral position is above the observer's horizon. This suggests that the echoes are caused by some phenomenon associated with this position, possibly justifying further research into these areas of near-Earth space.

REFERENCES

1. D. A. Lunan, *Spaceflight,* April 1973, 122-131;
2. C. Stormer, *Die Naturwissenschaften,* **33,** 643-651.
3. Van der Pol, B. *Nature,* **122,** 878.
4. J. Hals, World Radio (BBC, London) 23 November, 1934, 731; 30 November, 1934, 770; 7 December, 1934, 806; and 14 December, 1934, 844-848.
5. Villard, O. G, *QST,* Feb. 1970.
6. Villard, O. G, *QST,* May 1971.
7. Bracewell, R. N, *Nature,* **186,** 670
8. Bracewell, R. N, *Astronautics and Aeronautics,* **11,** 58.

*Mr. Lawton comments:*

Having read the draft of Mr. Sassoon's interesting paper, I would add the rider that the apparent connection between reports of LDE and the Trailing Trojan position can be further emphasized by a more pentetrating statistical analysis – in this particular case the Chi-Squared test.

Taking the values given in Sassoon's Table 1 and comparing the observed and expected results we have:

| Sector | Observed | Expected | $X^2$ | |
|---|---|---|---|---|
| -90/-150 | 13 | 15.33 | 0.355 | |
| -30/-90 | 18 | 15.33 | 0.464 | |
| +30/-30 | 24 | 15.33 | 4.899 | * |
| +90/+30 | 20 | 15.33 | 1.420 | |
| +150/+90 | 11 | 15.33 | 1.225 | |
| -150/+150 | 6 | 15.33 | 5.681 | * |
| Totals | 92 | 92 | 14.043 | |

where the expected result is an average of $\frac{92}{6}$ and $X^2 =$

$$\Sigma \frac{(0-E)^2}{E}$$

for the six sectors we have five degrees of freedom ($\nu = \eta - 1$) and reference to $X^2$ tables indicates that there is only 1 chance in 65 that the observed data were drawn from a rectangular distribution – that is, a distribution in which an approximately equal number of observations are expected in each cell. (Note the very high value for the 3rd cell and the very low value in the last cell, both marked *). We can therefore say that there is an anomaly in the distribution of these observations.

But we can go much further than this, for if the LDE phenomenon *is* associated with the Trailing Trojan area then we can propose the following hypothesis:

(a) There should be a *high* number of observations for the leading Anti Trojan Area (f = 20).

(b) There should be a *low* number of observations for the leading Trojan Area (f = 13).

(c) There should be a *high* number of observations for the Trailing Trojan Area (f = 24).

(d) There should be a *low* number of observations for the Trailing Anti Trojan Area (f = 6).

The figures in the brackets refer to the number of observations actually obtained – See Table 1.

Summing the 'Highs' and 'Lows' expectations according to the above hypothesis we have:

| | | | |
|---|---|---|---|
| Highs | (a + c) | = 20 + 24 | = 44 |
| Lows | (b + d) | = 13 + 6 | = 19 |
| | | Total | 63 |

Now our *statistical* hypothesis is that we expect an approximately equal number of observations in each cell but we see that the actual observations differ quite considerably. The $X^2$ test tells us that the probability of getting by chance such a large difference is 1/390. In most tests of significance we ask the question, 'Is there a significant difference'? regardless of the direction the data takes. But in the hypothesis outlined in paras: a, b, c, d, we actually postulate the 'direction' in which we believe the data will lie if our hypothesis is correct. For this reason, the test of significance becomes what is called a 'one tailed' test and we are therefore allowed to halve the probability given above which now becomes 1/780. In other words there are 779 chances that our hypothesis is supported – and only one chance that it is not supported – by the observed data. This significant result highlights the Operating capability of a Chi-Squared test.

If the Moon's possible contribution to the LDE observations is considered, we could add a further hypothesis and forecast a high frequency for the 'Moon' sector (f = 18) and a low frequency for the 'anti Moon' sector (f = 11). Although the ratio 11:18 is not significantly different from an *expected* ratio of 50:50 we may pool this observed data with that from the earlier hypothesis (para's a to d) and obtain:

| | | |
|---|---|---|
| High expectations | 44 + 18 | = 62 |
| Low expectations | 19 + 11 | = 30 |
| | Total | 92 |

Support for the LDE hypothesis is thus further enhanced for a $X^2$ test shows that the probability that the data was drawn from a population with a 50:50 ratio is 1/1480 – that is 1479 chances in favour of the LDE hypothesis and one against it, assuming as before that this is a 'one-tailed' test.

This remarkable 'goodness of fit' between the hypothesis and the observed data lends considerable support to the possibility of a connection between the occurrance of LDE and the positions of the Trailing Trojan or the Moon in the sky of the observer(s).

It is possible that the degree of fit could have been further enhanced if the observer's positions had been accurately recorded in some of the later tables. It is strongly recommended that this be done by any participants in future LDE work.

Once again I would stress the need for further active strides on these almost unique sectors of space which are so close to the Earth.

## SOVIET SPACE STAMPS

In celebration of Cosmonautics Day on 12 April – commemorating the epic flight of Yuri Gagarin in 1961 – a new postage stamp has been issued in Moscow. The six-copeck stamp depicts an Earth globe and the *Meteor* weather satellite system in red-orange, green-blue and violet.

Other recent Soviet issues include two 10 copeck stamps devoted to the flights of Soyuz 12, Soyuz 13.

**NEXT MONTH.** The August issue of *Spaceflight* will include a major illustrated feature by Charles A. Cross, giving a preliminary assessment of the remarkable pictures of the planet Mercury obtained during the fly-by of Mariner 10. There will also be a feature on "The Past and Present of Mars", filling in more results of the recent Soviet attempts to soft-land instrument capsules on the Red Planet, which adds weight to an inter-glacial water theory of Mars. Other articles appearing in this issue are: "The Moon and Dr. Berry" (commemorating the retirement from NASA of the astronauts' physician); "Doctor in Space", by astronaut Joseph P. Kerwin, and "The Soyuz Propulsion System" by David Woods.

The September issue opens a new B.I.S. enquiry into the industrial potential of Space Station and the Moon.

## MISSION TO MERCURY

Mariner 10, the first spacecraft to explore Mercury, reached the planet on 29 March passing on the dark side within 500 miles (805 km) of the surface. Photographs returned showed a surface heavily pock-marked by thousands of craters which in general are flatter and thinner-rimmed than those on the Moon, with rilles, hillocks and scattered ridges but no mountains. No moons were found.

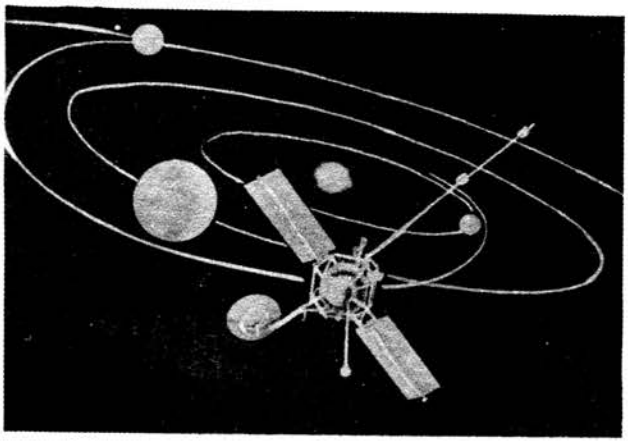
The planet appears to have a high density, probably with a high iron content, and a weak magnetic field about 1 per cent that of Earth, an extreme UV experiment indicated that a tenuous atmosphere – less than 0.1 per cent as dense as Earth's – has traces of argon and neon – also helium possibly produced by the decay of radioactive uranium in the planet's crust.

Despite the fact that spacecraft systems had to be turned off after an unacceptable surge in power consumption (and overheating) on 30 March, the mission must be counted as one of the most successful ever carried out in robot space exploration.

Launched on 3 November 1973 on the first dual-planet mission to Venus and Mercury, the craft was the first to use the gravitational attraction of one planet to reach another. It passed Venus on 5 February returning a full complement of scientific data including more than 4,000 photographs. The gravitational attraction of Venus altered the spacecraft's flight path, aiming it towards the orbit of Mercury. A trajectory correction on 16 March refined the flight path from a miss-distance of about 4,400 miles (7,000 km) on the sunlit side of Mercury, to the final trajectory.

Photography of Mercury began on 23 March at a range of 3.3 million miles (5.28 million km), with transmission of the early calibration photographs to Earth. A total of 2,000 photographs of Mercury was expected.

Photography continued daily as Mariner 10 closed on its target and was to continue after the point of closest approach as the spacecraft pulled away from Mercury.

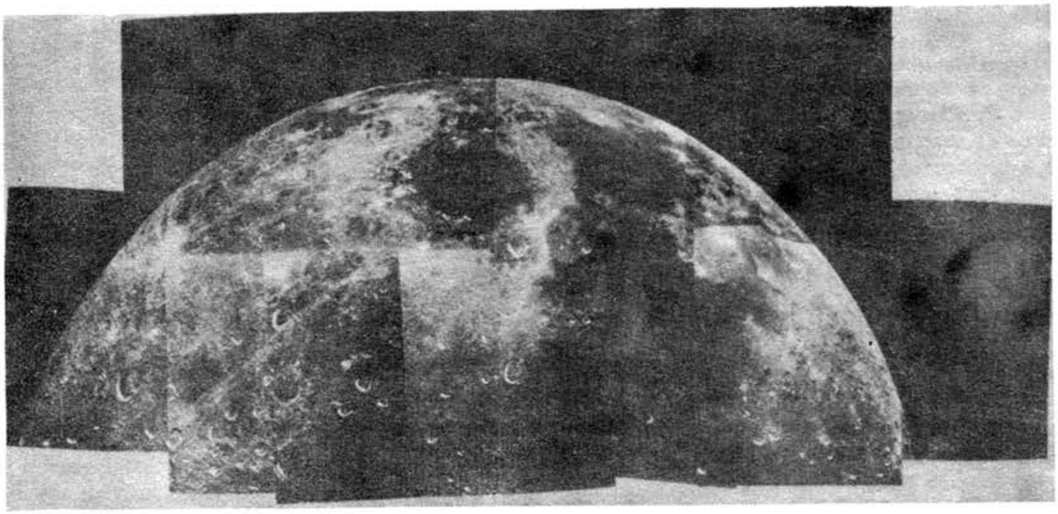


Mariner 10 was the first spacecraft to use the gravity of one planet, Venus, to reach another. In fact it made the Grand Tour of the inner Solar System photographing first the Earth, then the Moon, Venus and Mercury.

The incoming photography was designed with three basic objectives. The first was to obtain 90% coverage of the visible, sunlit portion of the disc at an approximate resolution of 1.5 miles (2.5 km). The second had the objective of attaining high resolution, 0.8 miles (1.3 km) of 30% of the visible disc. The third series sought a resolution from 0.5 miles (0.8 km) down to about 900 ft. (300 meters). This last series of pictures allowed the first detailed geological interpretation of the planet.

Planet Earth from Mariner 10 as observed on launch day 3 November 1973 at a distance of 120,000 miles (193,120 km).

*National Aeronautics and Space Administration*



GRAND TOUR OF THE INNER PLANETS. Mosaic of Mariner 10 photographs of the Moon, taken on 3 November 1973 as the craft began its journey to Venus, to test performance of the TV system prior to the eventual Mercury fly-by. Circular dark area at right centre is *Mare Crisium:* dark areas at lower left are *Mare Serenitatis* and *Mare Tranquillitatis.* Pictures were taken at 42-sec. intervals when spacecraft was about 68,000 miles (110,000 km) from the Moon.

*N.A.S.A.*

Mariner 10 view of the Moon from a distance of 70,000 miles (112,654 km) on 3 November. At lower centre is *Mare Humboldtianum.*

*National Aeronautics and Space Administration*

On 29 March, as the spacecraft flew past the dark side of Mercury, its scientific experiments searched for an atmosphere, measured temperature ranges on the surface, performed Sun and Earth occultations, and observed the interaction of the solar wind with the planet. The flight path past the dark side was chosen to allow the occultations, to observe the solar wind interactions and measure temperature changes from the night into the day side.

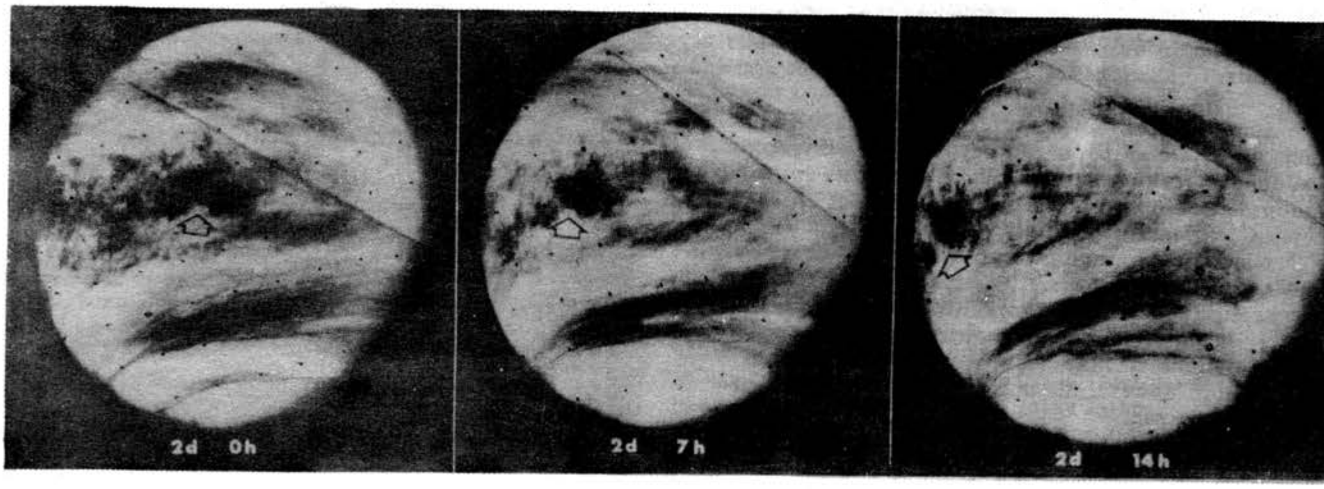
Scientific data were transmitted from the spacecraft at a rate of 22,050 bits per second to receiving stations equipped with 210 ft. (64-metre) antennae at Goldstone, California's Mojave Desert; Canberra, Australia, and near Madrid, Spain. Encounter at Mercury, on 29 March, occurred over the Goldstone station.

For the Mercury encounter period, the television experiment was divided into five parts. Encounter (E) was defined as the point of closest approach.

The first sequence was designed to cover a period of E minus 6.5 days to E–17 hours during which 6 full tapes (36 frames each) would be recorded aboard the spacecraft and played back to the Goldstone station. (A sequence of blue, orange, clear and UV filters was used throughout the encounter sequences).

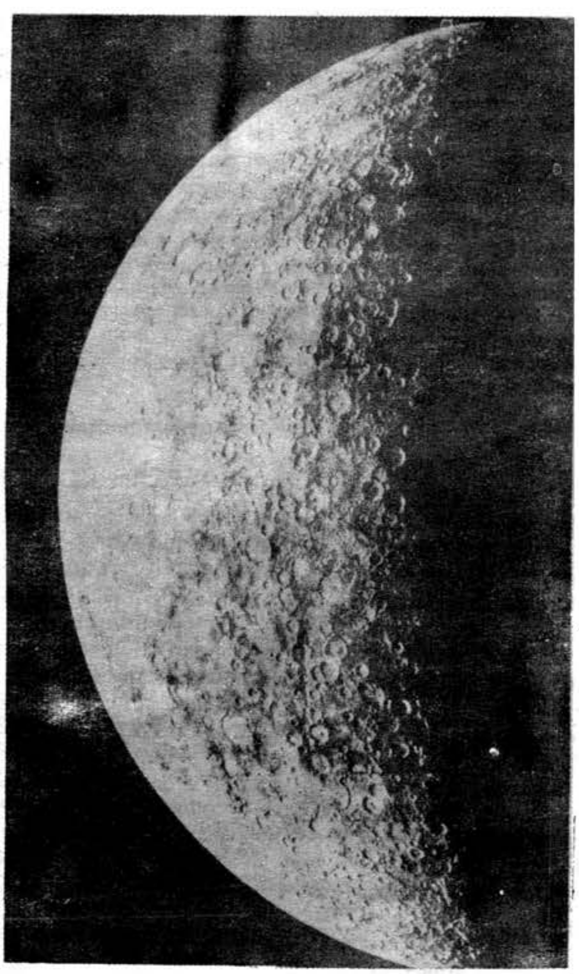
There were two searches in this period for possible Mercury moons. If Mercury had a small moon, or moons, they would not be detectable from Earth but should be visible in spacecraft photography. *As it turned out, an early report that a small moon had been discovered was found to be the result of a misinterpretation. The object was, in fact, a distant star.*

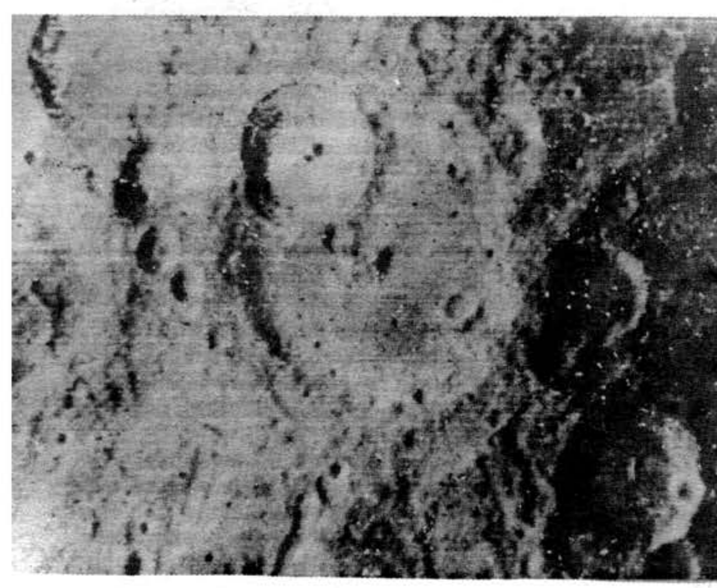
A Mercury diameter experiment was also performed by




Series of photomosaics of Venus taken at seven-hour intervals two days after Mariner 10 flew past the planet (from left, 10 a.m., 5 p.m. and 12 p.m. PDT on 7 February 1974). The pictures, taken through ultraviolet filters, show the rapid rotation of light and dark markings at the top of Venus' thick cloud deck. Size of the feature indicated by arrows is about 620 miles (1,000 km).

*United States Information Service*





*Left,* first close-up of Mercury. Photomosaic of Mercury from a distance of 124,280 miles (200,000 km), as fashioned from 18 computer-enhanced pictures returned by Mariner 10; about two-thirds of the planet's southern hemisphere is visible. Largest of the craters are about 124 miles (200 km) across.

*Right,* 'Kuiper' has been proposed as the name for the very conspicuous bright Mercury crater on the rim of the larger older crater. Professor Gerard Kuiper, a pioneer in planetary astronomy and a member of the Mariner 10 television team, died in December 1973 while the spacecraft was en-route to Venus and Mercury. Distance between camera and surface is about 54,930 miles (88,450 km). The bright crater is 25.5 miles (41 km) across and the larger one about 49.7 miles (80 km).

*United States Information Service*

the television experiment during this period to refine the existing value for the planet's diameter. The shape of Mercury (departures from a spherical shape) could also be determined in this experiment.

In addition to the taped photographs in this period, other frames were transmitted in real-time without being recorded. Real-time photos transmitted to Earth were in a low resolution format, leaving out some picture elements. Taped photographs were transmitted at full resolution.

The limitation in transmitting only low resolution photographs in real-time was the 22,050 bit-per-second transmission rate; because a picture was transmitted to Earth every 42 seconds, the interval between photographs was not sufficient to transmit an entire picture. When transmitting a taped picture, however, the entire high or full resolution frame could be sent.

These real-time transmissions were used to measure the albedo as a function of the phase angle in order to determine the reflective properties of Mercury at different lighting angles.

High resolution frames were used to construct photographic mosaics of the Mercury surface. The cameras viewed about one-half of the sunlit face of Mercury (one-fourth of the entire planetary surface) during approach to the planet.

The second sequence began at E-17 hours to E-3 1/2 hours. Eight half-tape loads (18 frames) were to be recorded and transmitted in this sequence. An ultraviolet airglow spectrometer experiment consisted of eight 10° slews back and forth across the planet.

A Mercury mosaic was programmed for E-13.3 hours and another at E-4.9 hours, the latter being important as a basis for locating later pictures covering smaller areas at a higher resolution. The resolution of this latter mosaic would have been about 2.5 miles (4 km).

The next sequence was scheduled from E-3.5 hours to E+4.45 hours. During that time, 612 high resolution partial frames were to be transmitted in real-time with 35 full frames to be taped (18 incoming and 17 outgoing) for later transmission.

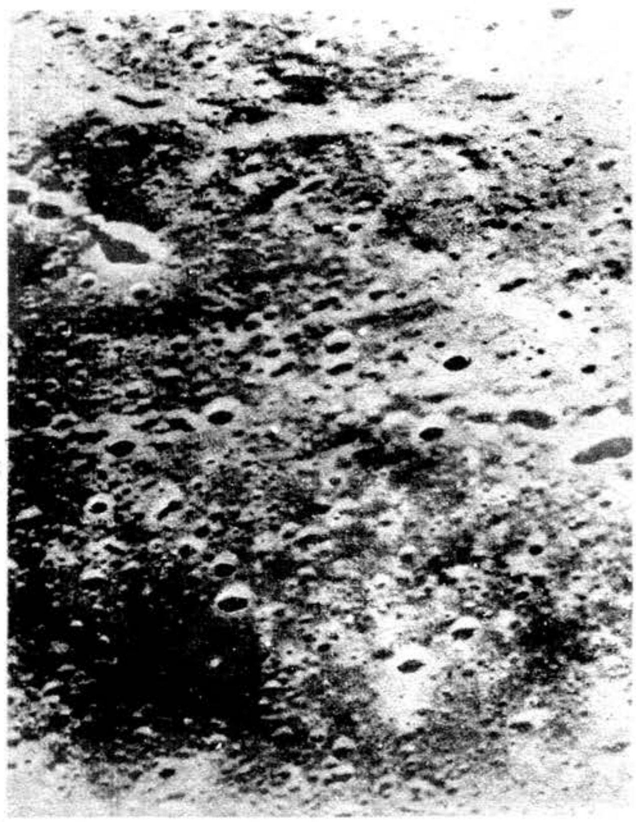
During this period, the Ultraviolet Airglow Experiment would perform three experiments: a helium search at E-2, an oxygen search at E-1, and an argon search at E. This was also the period in which Earth and Sun occultations occurred and the Radio Science Experiment and the Ultraviolet Occultation Spectrometer made atmospheric measurements.

In the meantime, the Plasma Science, Magnetometer, and Charged Particle Telescope experiments would observe the interaction of Mercury with the solar wind which emanates continuously from the Sun.

This sequence, which was partly frustrated by the power surge problem, was to have been nearly the reverse of the incoming sequence. There were to be 144 taped full frames and 144 real-time quarter frames. The Ultraviolet Experiment was to repeat the searches for oxygen and helium. Photography would again provide mosaics of the visible and sunlit disc.

A Far-Encounter sequence was to continue until E+13 days. The UVS was to scan Mercury daily until E+7 days when the instrument was to be turned off. Photography in this sequence was expected to total more than 500 taped and real-time frames and include a second satellite search and a second Mercury diameter experiment.

Of the suspected moon, which turned out to be a star, USIS Science Correspondent Everly Driscoll writes: The star is named 31-Crater. It is a class B-3 "very hot" star of fifth visual magnitude located in the constellation Crater.



Taken only minutes after Mariner 10 made its closest approach to Mercury, this is one of the highest resolution pictures obtained during the mission. Craters as small as 457 ft. (150 metres) across can be seen. The view, made from a distance of about 3,666 miles (5,900 km), covers an area 31 by 25 miles (50 by 40 km). Programme scientists say the relatively level area contrasts with the abundant relief visible in some close-up views on the opposite side of the planet. The long, narrow section of hills and scarps is similar to ridges in the mare material of the Moon.

*United States Information Service*

The observation of the star by Mariner 10 came late on 29 March as the ultraviolet, navigation and television teams working with the spacecraft at the Jet Propulsion Laboratory in Pasadena, California, completed 16 hours of search for an object in Mercury's orbit. Computer calculations comparing the field of view of the instrument and a star field pinpointed 31-Crater. Dr. A. Lyle Broadfoot of the Kitt Peak National Observatory, chief scientist for Mariner's ultraviolet spectrometer, spotted the star. At a Press conference on 31 March, Broadfoot and co-investigator Michael McElroy of Harvard University had shared their puzzlement over what their instrument had been seeing.

Computer calculations later revealed that the combined motions of the spacecraft, Mercury, the UV instrument and both Mercury and Mariner 10's relative motion to the Sun made the star appear as though it was moving. In fact when

the apparent orbit was extrapolated it looked like an elliptical orbit around Mercury. The apparent mystery, however, is still not completely resolved. On 27 March, two days from closest approach and still millions of miles from Mercury, the instrument saw the same source of light flash. The instrument was then pointing at Mercury, not at the star, which was in a different part of the sky. It was this initial sighting – an intense ultraviolet light that later disappeared – that began the drama of the "strange object".

"At the same time", said McElroy, "we thought there were three possibilities: Our instrument was not working; there was a peculiar star behind the planet; or Mercury had a very strange variable source of intense radiation in one region of the spectrum. We thought the latter possibility was the best at the time."

The source of radiation reappeared. The second time was when the ultraviolet instrument was looking off the edge of Mercury. After swinging around the planet, the instrument then looked back at Mercury and in the same region of the sky again saw the bright emission.

The fact that the scientists saw the same light source in a three-day period while looking at different regions of the sky near Mercury made the speculation about a possible moon seem plausible.

Now the question is, if the source seen prior to and after close approach to the planet was the star, what was the source of light two days earlier when the spacecraft was looking at Mercury? "That will have to be resolved," said Dr. McElroy. "It would be quite a coincidence to see two strange objects showing up in the same area of the spectrum, both in the background field around Mercury."

"On the other hand," he continued, "there are other indications that the night side of Mercury is the source of a variable radiation and is speckled by bright, flickering aurorae. The luminosity is presumably associated with the energetic electrons detected by other instruments on Mariner 10."

Another puzzle the discovery raises is about the star itself. Scientists had thought that ultraviolet light at the shorter wavelengths would be absorbed in inter-stellar space and would never reach Mariner's sensors. Yet when looking at the star, the instrument detected radiation near the short wavelengths for the alpha beta line of hydrogen and helium.

## COSMOS BIO-LAB

The examination of animals and other living organisms which were recovered on 22 November last year after a 22-day flight in the artificial satellite Cosmos 605, launched on 23 October, has been completed in Soviet scientific laboratories. The spacecraft carried rats, tortoises, insects, fungi and micro-organisms.

Novosti reports: This was a comprehensive and fully automated biological experiment, as a result of which scientists obtained valuable information about the effects of space flight, and especially weightlessness, on the structure and functions of living organisms.

A thoroughly-prepared and synchronised control experiment was carried out in one of the laboratories of the Institute of Medical and Biological Problems. Containers with the same number of living organisms as the containers on board the satellite were put inside a model of the satellite's landing module.

When Cosmos 605 returned to Earth a mobile biological laboratory went to the landing site to carry out a preliminary examination of the living organisms after their space flight.

The organisms which had been taken into space and those used in the control experiment were divided into a number of groups. In the first group were organisms which had made the flight and organisms which had gone through the control experiment, and these were studied immediately after the landing. In the case of another group the scientists waited for 25 days before beginning their examination. Some of the organisms were reserved for a study of the long-term after-effects of space flight.

The material collected is being processed at institutes of the USSR Ministry of Health, the Academy of Medical Sciences and the USSR Academy of Sciences.

"Our main success lies in the fact that we have succeeded in obtaining extensive and statistically authentic material on the effects of weightlessness upon living organisms," one of the directors of the experiment told a *Tass* correspondent.

"No biological space laboratory has previously had such a large number of test mammals on board, and this has naturally added greatly to the scientific value of the information obtained."

Vestibular experiments showed a certain sluggishness during the first few days, caused by the slowing down of the organisms' reactions following space flight.

Evidence was obtained which bears out the view that a long period of weightlessness has a considerable effect on metabolic processes. Animals, for instance, put on weight more slowly and showed a worsening of tissue respiration, a lowering of the body temperature, changes in some tissues and the inhibition of red marrow. Bones in animals' limbs became more brittle. There were changes in the weight of some internal organs and endocrine glands – the spleen, the thyroid gland, the adrenal gland and the kidneys.

At the same time, no pathological changes were discovered in the organisms and three to four weeks after the landing, the animals which had been in space did not differ from the control animals in most respects. They became active and lively and put on weight in the normal way.

For the first time during research in space biology, a second generation of insects was obtained in conditions of weightlessness. These were *Drosophila* fruit flies and specialists found no difference between the two generations as regards size and genetic information. This was also confirmed during observations of flour beetles which during the flight passed through various stages of development from egg to chrysalis. It should be noted that during experiments with micro-organisms it was established that weightlessness did not affect their viability or their genetic characteristics.

Effects of weightlessness on the development of plants were demonstrated in the experiment. The satellite carried a small "greenhouse" containing fungi. Under weightlessness, the fungi acquired strange shapes. In contrast to the fungi grown in the control experiment, they had thin curved stems and more massive mycelia.

Another notable success was obtained in the radiation and physical experiment conducted aboard the satellite and progress was made in further improving the system for protecting both the crews of spacecraft and the equipment from the effects of radiation.

The flight provided new data on the effectiveness of electrostatic protection against charged particles. Equipment for creating an electric field round a spaceship and for de-

flecting the flow of charged particles in space was tested, as also were new types of instruments for dosimetric control.

## WEATHER ROCKET CAMPAIGN

A record series of 79 rocket launches from 8 sites in the western hemisphere was completed earlier this year as part of a programme to determine daily variation in temperature and wind conditions in the upper atmosphere at the time of the spring equinox. The firings, made at regular intervals over a 24 hr period beginning at 12:05 p.m. EDT on 19 March, were made from locations in North Central and South America, the Caribbean Sea, and the Atlantic Ocean.

Single-stage Loki and Super Loki rockets carried meteorological instruments to heights of about 40 miles (70 km). The payloads were ejected and returned to Earth by parachute, readings of atmospheric temperature being telemetered to ground receiving stations. At the same time, the parachutes were tracked by radar to reveal wind conditions in the upper atmosphere.

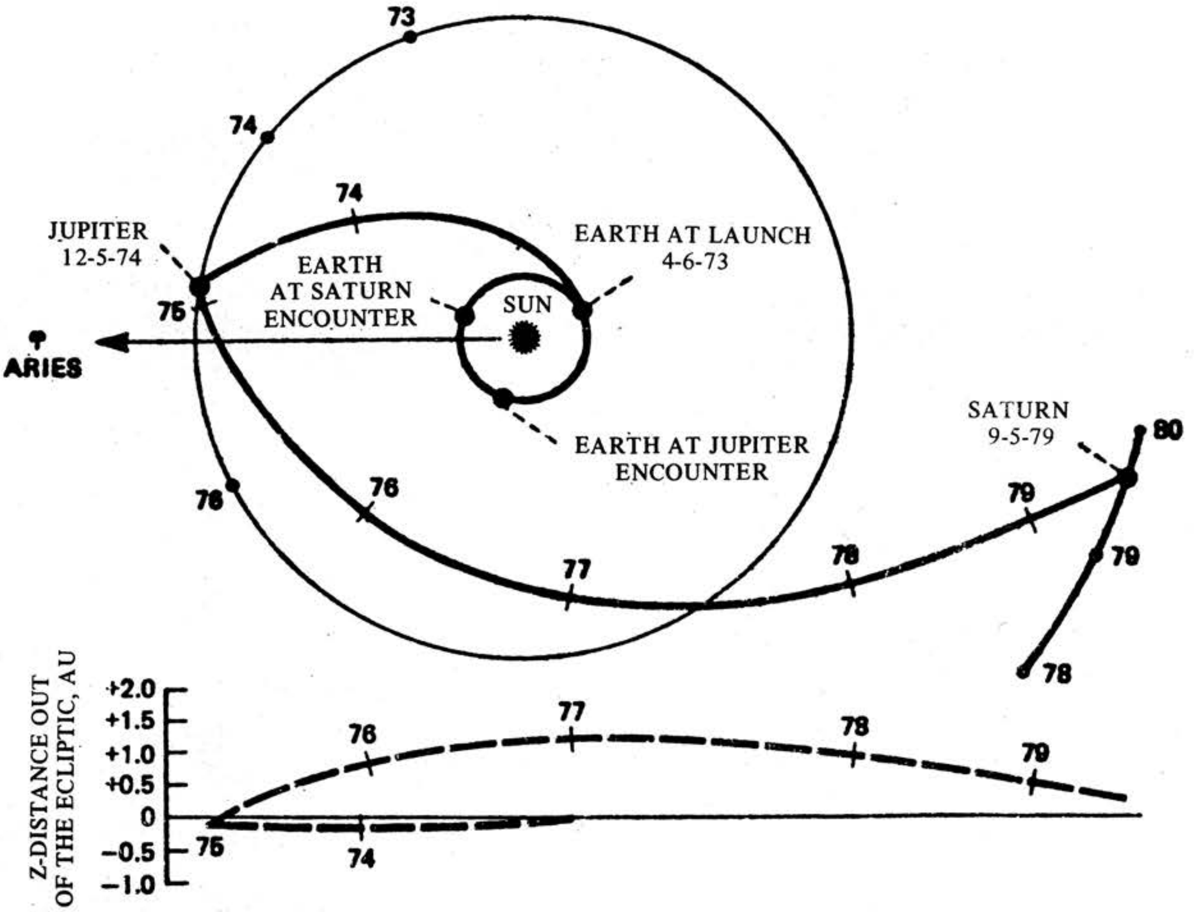
The series of launches was expected to bring scientists a better understanding of upper atmospheric circulation and temperature patterns, and should yield benefits in improved weather forecasting. Four of the launch sites – Mar Chiquita, Argentina, Natal, Brazil, Kourou, French Guiana, and Wallops Island, Virginia – are part of the Experimental Inter-American Meteorological Rocket Network. The other four – Ascension Island, Fort Sherman, Canal Zone, Antigua, British West Indies, and Fort Churchill, Canada – are in the U.S. Co-operative Meteorological Rocket Network.

## PIONEER 11 IS RETARGETED

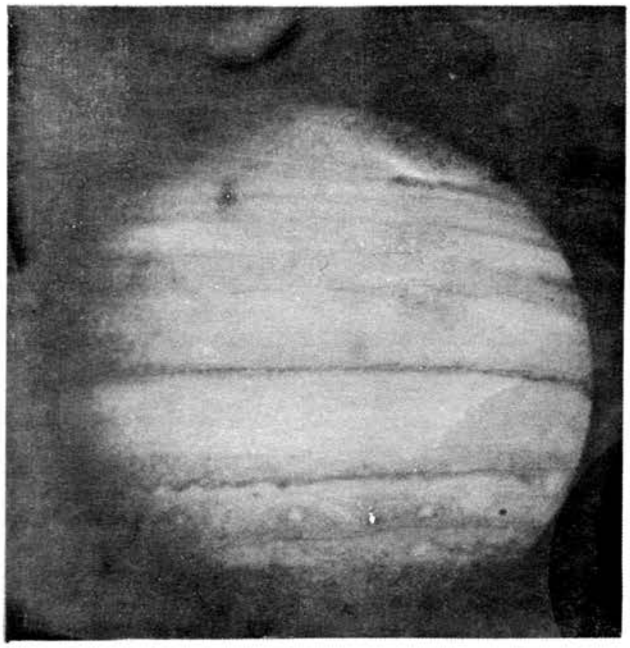
The course of Pioneer 11 has been changed to make it skim within 26,000 miles (42,000 km) of Jupiter, then fly back across the Solar System on an extended five-year trip to Saturn. The course change was calculated to give investigators much better data on Jupiter than would have been possible from a repetition of the 1973 Pioneer 10 mission. That spacecraft flew past the equatorial portion of Jupiter last December at a distance of 81,000 miles (131,000 km), obtaining photographs and measurements.

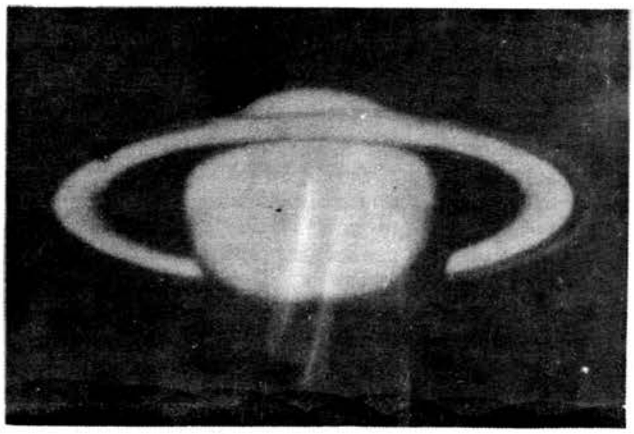
On its new course, Pioneer 11 will pass the giant planet closer to the polar region, covering a much wider range of latitudes and coming three times closer than its predecessor.

By firing Pioneer 11's on-board thrusters, controllers at NASA's Ames Research Center, Mountain View, California, aimed to bring the craft to within 26,000 miles (42,000 km) of Jupiter's banded cloud tops on 5 December. Pioneer will approach the planet from below Jupiter's south pole, then be




Pioneer 11. Revised flight profile showing gravitational "sling-shot" manoeuvre – Jupiter to Saturn.





*Top left.* This view of Jupiter in blue light shows never-before-seen aspects of the planet's cloud tops. Taken by the Pioneer 10 spacecraft as it flew past the giant planet last December, details of the picture now have been greatly improved by data analysis and computer processing at the Optical Science Center, University of Arizona, the white ovals with dark rims in the southern hemisphere have been observed through Earth telescopes, but never in the detail seen here. The largest of these cloud cells or ovals have a diameter about half that of the Earth. They appear to be rising cloud columns have been observed through Earth telescopes, but never in the detail seen here. The largest of these cloud cells or ovals have a diameter about half that of the Earth. They appear to be rising cloud columne with the darker rings around the edges being regions of downward motion of the surrounding clouds. In these darker regions, the cloud droplets may be subsiding into regions of higher temperature, where they evaporate, becoming an invisible gas, producing depressions in the clouds. The Pioneer Project is managed by NASA's Ames Research Center, Mountain View, California. The Pioneer spacecraft was built by TRW Systems, Redondo Beach, California. Pioneer 10, now well beyond Jupiter, will cross the orbit of Saturn in 1976, and leave the solar system altogether in 1987. Jupiter's next visitor, Pioneer 11, will have its course deflected to achieve a close approach to Saturn (*top right*) in September 1979. Two of the three rings around Saturn are visible in this photo taken through the 100-in. (254 cm) telescope at Mount Wilson Observatory in California. The first successful radar probe of Saturn indicated that the planet's rings are composed of large chunks of solid material in orbit like a swarm of tiny moons. Astronomers at the Jet Propulsion Laboratory in California bounced electronic signals off the rings a dozen times in December 1972 and January 1973, using the nearby Goldstone antenna. Dr. Richard M. Goldstein and George Morris Jr. reported: "We received much stronger bounceback signals than we expected from such a distance. From our radar results, the rings cannot be made up of tiny ice crystals, dust or gas, as previously theorized. Our echoes indicate rough, jagged surfaces, with solid material one metre in diameter or larger – possibly much larger." Recent technological improvements made it possible to extend the radar capability to Saturn, 1100 million km away, they said. The planet has a diameter of about 115,000 km and the rings extend outward to 140,000 km.

*United States Information Service*

pulled rapidly upward by Jupiter's enormous gravity, intersecting Jupiter's equatorial plane at an angle of 55°. The spacecraft will then exit from Jupiter, well above the planet's north pole.

The close approach to Jupiter will speed up the spacecraft to 110,000 mph (175,000 km/hr), relative to the planet. This speed, plus the high angle of approach to the disc-like radiation belts, should bring Pioneer through Jupiter's zone of intense radiation very rapidly. It is hoped that this will reduce the cumulative radiation dose to spacecraft systems to acceptable limits. If Pioneer 11 can survive this passage it will measure the thickness of Jupiter's radiation belt and pave the way for future Jovian orbiting missions planned for 1981.

Under the new plan, Pioneer 11 will fly in front of Jupiter (to the left as seen from Earth) as it moves in its orbit. The spacecraft will then pass behind the planet, emerging on Jupiter's right side. With such a passage, Jupiter's gravity and orbital motion will kill some of Pioneer's velocity, putting it into a looping orbit toward the opposite side of the Solar System. This will first bring Pioneer inside Jupiter's orbit, then far out beyond Jupiter's orbit until it intersects the orbit of Saturn and encounters the ringed planet.

If the course-change manoeuvre is successful, Pioneer 11 will reach Saturn in September 1979, 6½ years after its launch. This is well beyond the spacecraft's design lifetime, but there is a fair possibility that it will be at least partially operational and able to return data.

If Pioneer's imaging system continues to function, it could return man's first close-up views of Saturn and its rings. Preliminary data could be obtained on such things as the planet's radiation belts (if any),the nature of its rings, its heat environment, and other phenomena.

## PROCESSING VACCINES IN SPACE

Manufacturing vaccines in space vehicles in Earth orbit may make the difference between having vaccines of very low effectivity and vaccines which are extremely effective in controlling spreadable diseases, David W. Keller, Manager of Advanced Programmes Space Division, General Electric Company, believes. Processing vaccines in space "may help us to find a solution to the common cold or to the many things called the common cold," he said. Vaccines are used in the treatment of many diseases and respiratory ailments. Key among these are flu and the common cold.

Keller noted that there are a number of substances that could be manufactured or processed economically on space missions flown by the Space Shuttle in the 1980s. "The utility of resultant products should be high enough for distribution at profitable price levels," he said.

The pharmaceutical industry has spent millions of dollars during years of constant research to develop methods for refining and purifying such products as vaccines, serums, blood fractions, enzymes, and the like. This is necessary because even the very slightest traces of impurities can cause harmful side effects or disorders and because the concentration of the active agents in some experimental vaccines is too low to make them really effective.

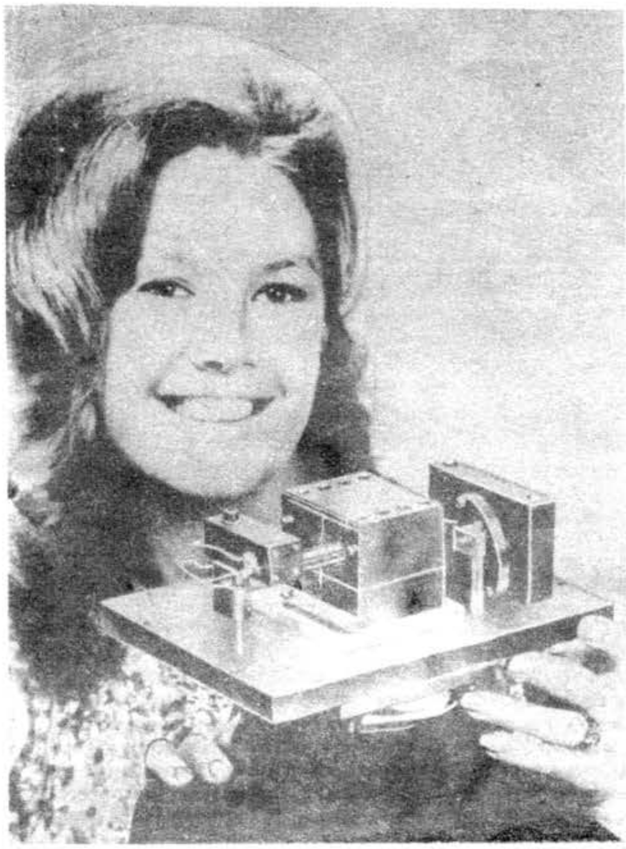
Such components can be separated or concentrated with a high degree of precision by a process called electrophoresis, a technique used routinely in medical laboratories on Earth today. It involves the application of electrical fields to solutions. The electrical fields cause components in the solutions to move and separate. As various particles are separated they can be removed from the solution. Gamma globulin, the blood component used as a specific treatment for several diseases, was first identified by this method.

"Earth's gravitational force, however," Keller said, "causes settling and convection currents and as a result liquids being subjected to electrophoresis must be confined in thin films or porous supporting materials thus limiting the procedure to small quantity testing".

Because no settling or convection should occur in a gravity-free or weightless environment, electrophoresis could be used "as an online processing technique for quantity production to separate desirable components from impurities", Keller said.

Two small demonstrations have already been performed on Apollo and Skylab flights, beginning the development of this promising space technique.

"In the Space Shuttle", "the processing of the 10 most used vaccines could be done, Keller concludes, advantageously by this method". If the usage level of vaccines by all nations were to approach that of the United States, this would require the processing of only one ton per year total of the ten typical vaccines with an estimated annual value in the millions of dollars.



Early laboratory model of the new GTE Sylvania laser for space communication capable of transmitting up to one billion bits of information per second.

## SPACE LASER

A laser capable of transmitting one billion bits of information per second between satellites is now being developed for a U.S. Air Force communication system by GTE Sylvania Incorporated, a subsidiary of General Telephone & Electronics Corporation. With peripheral equipment of less power and weight than present satellite radio networks, the laser system is reported to send more data faster. Moreover, it will operate on a narrow bandwidth, reducing interference or interception.

The neodymium YAG (yttrium aluminium garnet) laser will serve as transmitter for the new space communication system. Battery-powered light from a small lamp will stimulate the YAG material to produce a ¼-watt power beam capable of generating 500 million pulses per second. Pulses then will be "coded" to provide a data transmission rate of one billion bits per second.

GTE Sylvania reports that its work is based on new techniques for stabilizing the beam and cooling the laser. Conventional laser lamps are cooled by water or gas methods that are impractical for space applications. The new system uses conductive cooling where heat is dispersed to the body of the satellite and radiated into space.

## MIKHAIL TIKHONRAVOV

Mikhail Tikhonravov, one of the pioneers of Soviet rocket technology, died on 4 March 1974 at the age of 73. A leading rocket designer, he took part in the development of the first artificial Earth satellites, manned spacecraft and automatic space stations.

A corresponding member of the International Astronautical Academy, Mikhail Tikhonravov was born in 1900. After graduating from the Zhukovsky Air Force Academy in 1925, be began a career in aviation and was one of the pioneers of glider and aircraft engineering in the USSR.

In the early Thirties he became fascinated by the problems of rocketry and space exploration and on several occasions met Konstantin Tsiolkovsky. From 1933 he worked with Sergei Korolyev on the first Soviet rocket with a liquid propellant engine and subsequently devoted all his energy and knowledge to the solution of numerous design problems and latterly assisted in the education of specialists in the design

and engineering of rocket and space devices.

In his recent book, *Development of Rocketry and Space Technology in the USSR,* the veteran Soviet rocket engine designer Valentin P. Glushko writes: "In 1933 the first Soviet hybrid-propellant rocket, designed by M. K. Tikhonravov, and built by the Korolyev team, was launched at the Nakhabino range [near Moscow]".

"The take-off weight of the 2.4 metre long rocket was 19 kg; its propellant weight 5 kg; the engine produced a thrust of 25 to 33 kg; its thrust chamber pressure ranged from 5 to 6 atmospheres. The engine used liquid oxygen delivered into the chamber under the pressure of its own vapours and solidified gasoline which was placed in the combustion chamber (1 to 1.5 kg). It was fired from a vertical ramp. During the first trial launching on August 17, 1933, it reached a height of about 400 metres before the combustion chamber burned through. The flight lasted 18 seconds. During the second launching (autumn 1933) the rocket reached an estimated height of 100 metres when the engine exploded. In 1934 the rocket underwent several successful trials and reached a height of 1,500 metres".

## SPACE ATTACK ON SCREWWORM

A remote sensing test project to assist in eradicating the screwworm from Mexico using ground, air and space techniques is planned by officials from NASA's Johnson Space Center and representatives of the Mexican National Commission for Outer Space (Comision Nacional del Espacio Exterior).

The screwworm is a grub or lava which destroys cattle, poultry, and wildlife in the warm regions of the Americas. It develops from screwwormfly eggs laid in open sores and in the navels of new-born animals. The grub grows to a length of about half-an-inch by eating living flesh, frequently crippling or killing large numbers of domestic animals. Actual loss to the livestock industry has frequently exceeded $200 million annually.

The eradication programme is being conducted by the Mexican-American Commission for the Eradication of the Screwworm, established last year by the secretaries of agriculture of the two countries.

At one time, screwworms infested the United States from Florida to California and as far north as Nebraska. During the past two decades, they have been kept in check in the U.S. by dropping billions of sterile flies to mate with females in the infested areas.

An active programme by the U.S. Department of Agriculture succeeded in pushing the screwwormfly out of the United States. For several years, a 300-mile-deep buffer zone has been established along the northern border of Mexico from the Pacific Ocean to the Gulf of Mexico. Then, due to a mild winter, the screwwormfly managed to reinfest parts of Texas in 1972, causing an estimated $100 million in damage to livestock.

Beginning in 1975, a joint effort by the American and Mexican Governments will attempt to eradicate the insect throughout Mexico, maintaining a new buffer zone across the narrow Isthmus of Tuhuantepec. This new corridor will reduce the cost of maintaining the cleared zone to a fraction of present levels.

To bring about the eradication of screwwormflies in Mexico, agriculturists must have accurate reports on environmental conditions that affect the breeding habits of the flies. In the United States, information was communicated quickly through an extensive network of weather stations.

In Mexico, an estimated 260 additional weather communications links would have to be constructed to provide similar data. However, scientists in the Earth Resources Program Office and the Health Applications Office of NASA's Johnson Space Center believe that sensor data provided by the Earth Resources Technology Satellite (ERTS), ITOS weather satellites and similar space vehicles can be combined with information returned by a Mexican remote sensing aircraft to provide detailed reports on soil temperature, moisture, and vegetative cover – all of which affect the breeding patterns of the screwwormfly. If satellite data can accurately pinpoint potentially favourable conditions for screwworm infestation, this will aid flight planners immensely in distributing the sterile flies.

The test site selected for the project by a joint team from Mexico and the United States is an area 50 miles wide by 100 miles long, with its centre at Cordoba, a city midway between Mexico City and the Gulf Coast port of Veracruz.

At the remote sensing test site, measurements from equipment on the ground will be collected to be compared with the results of analysed data provided by the Mexican aircraft and the twice-daily overflights of the weather satellites. The region around Cordoba contains both lowland and highland plains, major breeding areas for the screwwormfly.

Although screwworms do not pose a serious threat to human health, Dr. Charles M. Barnes, Manager of the Health Applications Office at JSC, says that remote sensing techniques tested in Mexico may play an important role in understanding insect ecology. Barnes points particularly to the possibility that remote sensing technology may help extend the sterile fly eradication technique to other insects, including the disease carrying tsetse fly. The tsetse fly is so great a danger to the health of humans and animals that thousands of square miles of Africa are made virtually unfit for habitation..

The experimental phase of the remote sensing project in Mexico is underway and is expected to continue for approximately a year. If the techniques being developed are successful, they may be integrated into the operational screwworm eradication programme, being conducted by the two nations.

## MORE NASA RETIREMENTS

Dr. Homer E. Newell, NASA Associate Administrator, announced his retirement from the agency, effective 31 December 1973. In announcing Dr. Newell's departure, Administrator James C. Fletcher said, "He has served this agency with distinction and dedication and he will be sorely missed," noting that "Dr. Newell's efforts in the space programme antedate the birth of NASA. He will continue temporarily with NASA to complete work in which he is directly involved. We wish him all the best in the future".

An early member of the NASA Headquarters staff, Dr. Newell transferred to the newly organised agency from the Naval Research Laboratory in October 1958. He had held his present position since 1967. Prior to that he served for four years as Associate Administrator for Space Science and Applications.

During his tenure with the Naval Research Laboratory he served from 1944 to 1958, as theoretical physicist, mathematician, section head, head of the Rocket Sonde Branch, and acting superintendent of the Atmosphere and Astrophysics

Division. During part of this period he was Science Program Coordinator for Project Vanguard.

Mr. Vincent L. Johnson, NASA's Deputy Associate Administrator for Space Science, also announced his retirement from the agency. Johnson's tenure in the post dated from 1970.

In commenting on Mr. Johnson's departure, NASA Administrator James C. Fletcher said, "Mr. Johnson has been an able and conscientious leader in advancing our unmanned space programmes;we are sorry to see him go".

From 1964 to 1967 Mr. Johnson was Director of the Launch Vehicle and Propulsion Programmes in the Office of Space Science and Applications. He was responsible for the management and development of the light and medium launch vehicles used in NASA's unmanned Earth orbital and deep space programmes. His office also conducted research into future agency propulsion requirements.

## WESTERN UNION IN ORBIT

A geo-stationary satellite designed for communications within the United States was launched from the Kennedy Space Center, Florida, on 13 April by a Delta 101 rocket. Called Westar, it embodies no significant technological advances yet it marks an important milestone. Westar's distinction, writes Walter Froehlich, lies in the economic arena. It is strictly a business venture by a private, investor-owned corporation which paid for its construction and will operate it at its own expense.

The corporation, Western Union, widely known for its telegram service, plans to use Westar for the transmission of telegram messages, telephone calls, digital data, facsimile and television programmes. From fees paid by the users of these services, the corporation hopes to earn a profit. If Westar's costs exceed the income, Western Union must bear the loss.

The only part of the project involving any government agency was the launching of the satellite by the National Aeronautics and Space Administration. Western Union paid NASA for the Delta 101 rocket and reimbursed NASA for all other launch costs. The government served merely as a transportation agency because the required rockets and launch facilities are not available privately. The U.S. Government also issues licenses for the use of the radio frequencies equired by the satellite, and exercises certain regulatory functions over the public utility aspects of Westar.

After Westar's orbital path had been adjusted and its equipment fully tested, the satellite was expected to begin full operation, probably in August, between five Earth stations near New York; Atlanta, Georgia; Dallas, Texas, and Los Angeles.

The drum-shaped, 6 ft. diameter, 1,265 lb. Westar will carry 7,200 telephone conversations or 12 colour television channels simultaneously, or a combination of fewer voice, data and TV transmissions.

This communications capacity will be doubled after an identical satellite, Westar 2, to be launched in June, goes into operation for Western Union. A third satellite, Westar 3, will be held in reserve to replace or supplement the others if needed. Each satellite, powered by 20,500 solar cells, is expected to have a working life of about seven years. By then the fuel needed to reposition it occasionally will be exhausted.

This space communications system will augment and provide alternate channels to Western Union's ground network of conventional lines and microwave connections. However, the satellites will increase the reliability and quantity of available service of the Western Union system. To be commercially attractive, they will have to prove themselves competitive in cost and operational quality with ground-based systems. Experience with other communications satellites indicates the Westar system will easily pass that test.

Five other communications companies have also announced plans for domestic U.S. satellite communications systems beginning with launches in 1975. Ground terminals for most of these systems will be in other cities, but some of these companies will compete with the Westar system. One competitor, RCA (Radio Corporation of America), has been offering space communications to U.S. customers since January by using one of two satellites owned and operated by Canada in that country's domestic satellite communications system known as TELESAT.

RCA has temporarily leased several channels on Canada's Anik 2 satellite launched in April 1973. Anik 1, which is nearly identical to the Westar satellites, was launched in November 1972. Because of their position above the equator, the Canadian satellites can be used for communications for all of North America.

However, RCA plans its own network of three satellites of a new design to be launched beginning late in 1975. RCA also plans to enlarge its present complement of ground terminals which now consists of one station each in New York and San Francisco and two in Alaska.

Ironically, the United States which pioneered space communications is a late-comer in installing its own domestic satellite communications network. The reason is that, except for the state of Alaska, the United States already has one of the world's most extensive networks of telephone, telegraph and microwave services, and until recently there was little demand for large additional transmission capacity. The United States used its advanced technology in recent years to build the global INTELSAT system which now embraces a network of 88 Earth receiving and transmitting stations in 53 of INTELSAT's 84 member nations.

In Canada, which has large sparsely populated areas where terrain and weather make land-based systems difficult or impractical, the TELESAT system – using satellites built and launched by the United States – filled immediate needs.

The Soviet Union, where communications also were poor in remote regions, has operated its own domestic satellite communications system for several years. The Soviet Molniya system uses satellites in a highly elliptical orbit which keeps them alternately above the horizon of the large Soviet land mass for several hours each day.

Of the new technologies which have emerged from space exploration, communication via satellite has become the most widely adopted and the fastest-growing. Several nations are considering the establishment of domestic satellite communications systems using INTELSAT satellites. The U.S. Government has stopped most of its research in this field because current satellites are sufficiently advanced for commercial use so that further development can be handled profitably by private industry.

A maritime space communications system for ships (MARISAT) is planned for 1975 by the United States with satellites above the Atlantic and Pacific oceans. Discussions have also been progressing between the United States, Canada and European nations for a joint satellite communications system for aircraft (AEROSAT).

## HYDROGEN ENERGY BIBLIOGRAPHY

A hydrogen energy bibliography with abstracts – believed to be the most comprehensive ever compiled – has been published by the Energy Information Center at the University of New Mexico, Albuquerque. The Center was recently established as a cooperative effort by the University's College of Engineering and the NASA-sponsored Technology Application Center there to serve as a focal point for the dissemination of information on the broad field of energy.

NASA has helped stimulate interest in hydrogen energy by its successful development of fuel cells to power space vehicles and its use of liquid hydrogen as a high-energy, pollution-free rocket fuel. The new bibliography, entitled *Hydrogen Energy*, contains more than 900 references and covers the period 1953 to 1973. Supplements will be published annually. A special quarterly update service will be available on a subscription basis.

In view of the increasing shortages of conventional energy sources, *Hydrogen Energy* should be particularly valuable as an introduction to the potential use of hydrogen as an energy carrier and a secondary energy source.

The cumulative *Hydrogen Energy* volume is $25 per copy. The quarterly up-date service is $50 extra. Further information may be obtained from the Energy Information Center, Technology Application Center, The University of New Mexico, Albuquerque, NM 87131.

## EARTH OBSERVATORY SATELLITE (EOS)

Mercury, Gemini, Apollo and Skylab astronauts took thousands of pictures from space. Once they saved a small village in Mexico. A lake above the village filled with rain water. No one knew when the storm would abate. The choice: move people out, open the dam and flood the village, or wait until the dam broke. Astronauts looked at the storm clouds beneath them and told Mission Control the weather was breaking; the dam would hold.

An unmanned spacecraft called Earth Resources Technology Satellite has been scanning the planet for two years, reporting on snow pack in winter, range grass in summer, crop damage in spring, harvest in autumn and pollution the year round. Camera-laden aircraft and ground observers can do many of these tasks. But aircraft must take hundreds of photos to cover the area a spacecraft sees in a single pass; and ground observers never see the big picture.

Now NASA plans to do even better with a new generation of spacecraft called Earth Observatory Satellites, or EOS. Earlier this year three major aerospace companies were selected to perform parallel systems definition studies for EOS missions: General Electric Company, Valley Forge, Philadelphia; Grumman Aerospace Corporation, Bethpage, New York; and TRW Systems Group, Redondo Beach, California.

These studies are to provide low-cost modularised spacecraft capable of supporting a variety of research and development applications missions. EOS will provide a stable platform for testing sensors and collecting remotely sensed data for a number of user applications.

The EOS spacecraft will be designed for launching by conventional rockets and by the Space Shuttle in launch re-supply and retrieval modes. The first application mission being studied is related to land and water use.

The studies, managed by the Goddard Space Flight Center, are to be completed in six months at approximately $600,000 each. The first satellite is expected to fly in 1978-79.

The new spacecraft is expected to be a considerable advance over existing systems. Whereas today's Earth-studying satellites see only the patch of land directly below (covering the same area every 18 days), EOS will carry new "pointable" instruments that look in many directions. They will scan pre-planned targets or perform *ad hoc* tasks like hurricane or flood assessment, or report the spread of some new crop disease. Later versions will report on such things as pollution's causes and effects. Each will carry its own set of instruments that can be changed when necessary.

The space agency is working hard with industrial teams to achieve the widest possible dissemination of Earth resource data. No one benefits if pictures get lost in a file cabinet or computer. TRW Incorporated has worked out new ways to extract hidden information from ERTS photos and performs the service for NASA and other users.

The aim of EOS is to affect everyone's life in such fields as crop management (helping keep down the cost of food), flood control (curbing loss of life and property), and finding new oil resources (to help solve the energy shortage) – and at the lowest possible cost. Working with ERTS pictures, scientists have discovered cattle forage in Arizona deserts, oil reserves in India, damage to Canadian forests from sulphur dioxide, new timber in California, and the breeding site of desert locusts in Saudi Arabia. They found that land-use practices in Mali, West Africa, may have caused serious climate change and depleted the soil. And they mapped unknown regions in Bolivia.

One scientist remarked that, with the right spacecraft at the right time, his colleagues could have predicted last year's failure of Russia's wheat crop. "Since the Southern Hemisphere's planting season comes months later," he said, "we could have planted heavily there and avoided the world-wide wheat shortage – and bread that's more than 60 cents a loaf".

## AEROSAT AIRCRAFT ANTENNA

A further contract for the engineering and environmental testing of low gain L-Band aircraft antenna systems has been awarded to the British Aircraft Corporation, Electronics Systems Group, as part of a research and development programme to produce avionics equipment for the proposed experimental international Joint Aeronautical Satellite (Aerosat) Programme. The contract awarded by the Ministry of Defence (Procurement Executive) is worth £32,000.

The antenna system consists of two groups of antennae to be mounted on either side of an aircraft. Six slot-dipole elements make up each antenna group, complete with phasing and switching networks which permit the antenna beam to be steered without mechanical movement. The system has been designed with Concorde and other transoceanic aircraft in mind and each antenna group can be fitted flush with the fuselage skin. The overall antenna radiation pattern should permit a minimum gain of 4 db (relative to circular isotropic) at all angles in the upper hemisphere of coverage greater than $10^0$ elevation.

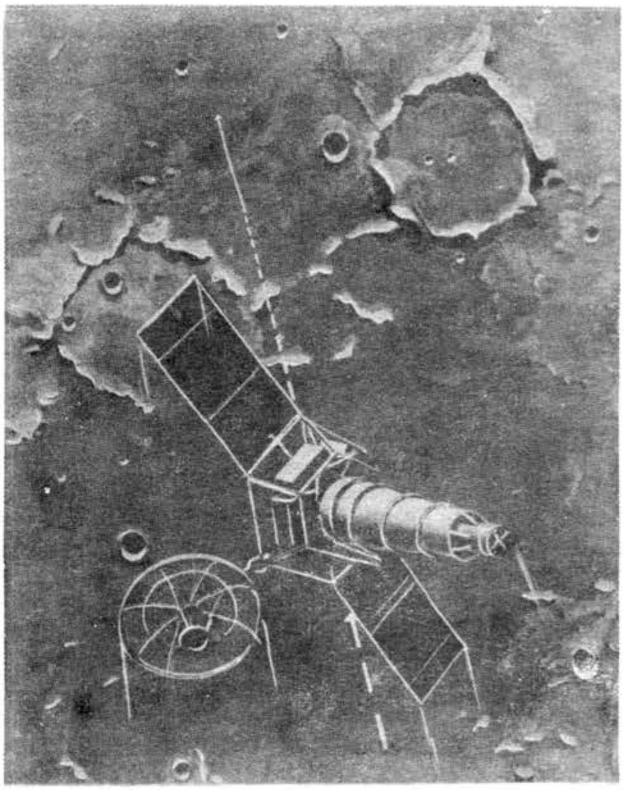
Two of the systems will be delivered to the Royal Aircraft Establishment Farnborough and flown in trials later this year.

*[Continued on page 279*

# RANGER 7



**A retrospective look at major space achievements by David Baker**



**Introduction**

July 31, 1964, will long be remembered by personnel at the California Institute of Technology's Jet Propulsion Laboratory as the date when space-faring robots made a bid for supremacy. On this day a spacecraft called Ranger hurtled to destruction on the cratered surface of the Moon, but not before it had sent back to Earth some 4,316 views of the approaching lurrain. These were the first true close-up views of the Moon and the event, marked now by its tenth anniversary, will go down as a landmark in space history.

**Prelude to the Moon**

Although itself a success, Ranger 7 had emerged only after a six-vehicle run of failures spanning nearly three years of effort and five years of development. The project was born in 1959 with a plan to develop a common "bus" for carrying payloads to the Moon and planets without major re-design or modification. This was seen as a way of keeping costs down and ensuring flexibility of operation. Within two years the plan was ousted due to problems with the Atlas-Centaur launch vehicle and work began on a smaller Mariner for the planets while retaining the Moon-bound Ranger for Atlas-Agena flights.

Ranger 1, a 675-lb engineering test spacecraft, was launched on 23 August 1961. The Agena failed to re-start for the desired duration and Ranger stayed in an elliptical orbit. This was the fate also of the second Ranger launched 18 November. Both flights were intended to follow a 500,000 mile ellipse before ultimate burn-up in the atmosphere.

1962 saw test flights of the Block II model, a Ranger designed to soft-land an instrumented package on the lunar surface. This package would ride piggy-back on the spacecraft and separate just before impact to retro-fire a solid propellent motor and bounce to a "soft" landing. Ranger 3, the first of these modified designs, got off the launch pad on 26 January. A failure in the launch vehicle caused it to miss the Moon by more than 2,200 miles and it swept on into an orbit of the Sun.

Ranger 4, launched on 23 April, reached the Moon after a 64-hr. flight but a sequencing failure prevented it from releasing the capsule. Ranger 5 was similarly dogged by ill-luck. Following launch on 18 October it missed the Moon by 450 miles and, like Ranger 3, went into solar orbit.

By now pressure was being applied to re-design the spacecraft yet again and come up with a more reliable vehicle. Four more Rangers were ordered and the basic goal of the programme was re-orientated from a capsule-landing objective to a photo-reconnaissance role. A battery of six TV-cameras would view the surface all the way to impact.

Suitably modified, Ranger 6 got off the ground on 30 January 1964. A high voltage arc in the TV system destroyed all hope of a successful flight but it did impact the Moon after a near-66-hr. cruise.

**Success at Last**

At 11:50 a.m. local time on 28 July 1964, Ranger 7 sped away from the Cape Kennedy launch pad and began a 68 hr. 35 min. flight to the Moon. Hurtling toward the dusty surface of *Mare Cognitum*, a basaltic plain south-west of Fra Mauro, Ranger began sending its TV images back to the control centre at the Jet Propulsion Laboratory. From a distance of 1,321 miles all the way down to impact the cameras transmitted valuable pictures of the Moon's surface. The final view, showing an area 98 by 163 ft., was shot from an altitude of just 1,600 ft. and a fraction of a second later Ranger 7 had plummetted to destruction at nearly 6,000 m.p.h. Nearly eight years later the cameras of Apollo 16 recorded the small, 45-ft. diameter crater made by the impacting spacecraft.

It had been done. After six failures Ranger had successfully shown the Moon's surface in immaculate detail. Two more Rangers, launched on 17 February and 21 March 1965, were equally successful as they sped to a lunar graveyard in the *Mare Tranquillitatis* and the crater *Alphonsus* respectively. In all, some 17,267 photo's were transmitted to Earth before Ranger gave way to the sophisticated Surveyor and its five soft-landings in the period 1966-68.

The programme could hardly be called a resounding success from start to finish but the unqualified success of Rangers 7 to 9 vindicated the effort applied over six years of development and operational flights. Without the basic information from these brief reconnaissance flights Surveyor would have had adverse odds stacked against its projected success. We remember the tenacious will of Ranger personnel at NASA's Jet Propulsion Laboratory as, ten years on, Ranger 7's birthday reminds us again that the road to the Moon had foundations of human dedication, personal resolve and untiring effort. Those who remember 31 July 1964 will never forget the ebullience felt at Man's first-generation Moon robot. Success is usually built on bitter disappointment and much nocturnal diligence and effort. Ranger 7 was the culmination of all that is best in the pioneering efforts of space exploration.

# TITAN III-E/CENTAUR



By M. W. Howard

## Introduction

During the late 1960's it became apparent to the National Aeronautics and Space Administration that a new launch vehicle would be required. The faithful Atlas-Centaur combination was already performing sterling work under the direction of the Lewis Research Center as the launch vehicle for the Surveyor spacecraft to the Moon and would later be used to send other spacecraft to Mars, Venus, Mercury, and Jupiter. In terms of power the next available vehicle was the prohibitively expensive Saturn IB which, because of its cost, could only justifiably be used to launch manned spacecraft and even then it was only capable of placing them in Earth orbit.

To bridge this gap NASA awarded a contract to General Dynamics Convair Aerospace Division to develop an improved Centaur vehicle that could be mated to either the Atlas or a slightly modified USAF Titan III booster. Martin Marietta was contracted to study necessary modifications to the Titan vehicle and the existing Titan launch facilities at the Eastern Test Range. In 1969, the Titan/Centaur was given the go-ahead when it was earmarked as the launch vehicle for the two Viking spacecraft due for flight in July-August 1975.


Titan IIIE/Centaur on Complex 41 at the Kennedy Space Center, Florida.

*National Aeronautics and Space Administration*

## Configuration

Together the Titan III-E booster and Centaur D-1T second stage have an overall height of 48.8 metres (160 ft.). Total launch weight is 64,000 kg (1.4 million lb.). To connect the 2 main stages, a 3.05 metre (10 ft.) diameter Interstage Adapter is required. This Adapter has a length of 2.9 metres (9.5 ft.).

To protect the payload the Lockheed Missiles and Space Company has developed the Centaur Standard Shroud (CSS) which also covers the entire length of the Centaur vehicle. Capable of accomodating a payload of almost 8.5 metres (28 ft.) in length, the CSS is 17.6 metres (58 ft.) long and 4.2 metres (14 ft.) in diameter.

## Titan III-E

The Titan III-E booster itself comprises 3 stages. Two strap-on Solid Rocket Motors (SRM) develop a total thrust of 2.4 million lb. Each SRM is 3.05 metres (10 ft.) in diameter and 25.9 metres (85 ft.) in length. Stage O, as the strap-ons are known, employ aluminium and ammonium perchlorate propellents which burn for almost 2 minutes at lift-off. A slender nitrogen tetroxide tank is mounted on the side of each SRM to provide thrust vector control. The Titan's first and second stages – Core Stages 1 and 2 – are also 3.05 metres in diameter. Both use as fuel a 50-50 blend of hydrazine and unsymmetrical dimethylhydrazine, the oxidant being nitrogen tetroxide.

Stage 1 is 22.2 metres (72.9 ft.) long and at lift-off the Aerojet YLR87AJ-11 twin chamber engine produces 520,000 lb. of thrust burning for some 2.5 minutes. Due to the tremendous amount of heat generated by the SRM's most of the Stage 1 engine is enclosed by a heat shield assembly. Core Stage 2, the final part of the Titan to come into operation, has a length of 7.1 metres (23.3 ft.). Whereas the first stage engine has two gimballing thrust chambers, the second stage has only one to provide directional control. This smaller Aerojet YLR91AJ-11 engine provides 101,000 lb. thrust firing for 3.5 minutes before the Titan hands over orbital insertion to the Centaur D-1T.

## Centaur D-1T

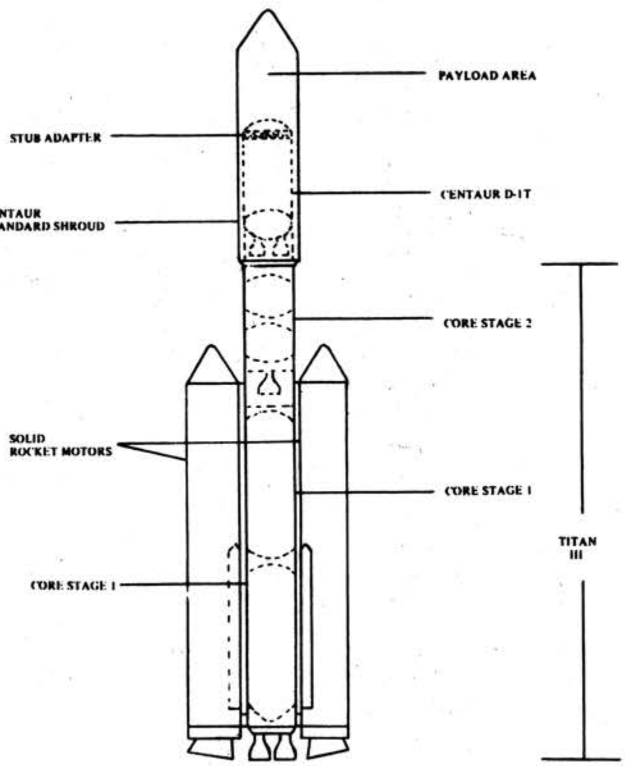
The modified Centaur vehicle is 9.1 metres (30 ft.) long and 3.05 metres (10 ft.) is diameter. Pressure stabilized stainless steel a mere 0.3 mm. (0.014 in.) in thickness is used to form the cylindrical tank. Due to the fragility of this structure the vehicle must either be pressurized or stretched on a specially designed cradle to prevent collapse in the unfuelled state.

In order that the Titan/Centaur may be used to place spacecraft into a synchronous orbit the Centaur has been given a new insulation system to allow the vehicle to coast in space for periods of up to 5.25 hours before restarting its engines.

A stub adapter above the propellent tank supports the forward equipment module. To support larger payloads in excess of 1,814 kg (4,000 lb.) a truss adapter connects to the stub adapter. The propellent tank itself contains a double-walled vacuum insulated bulkhead to separate the liquid oxygen and liquid hydrogen.

A total 30,000 lb. of thrust is provided by the Centaur's two RL-10A-3-3 engines used for insertion into orbit and other major manoeuvres. Once in orbit attitude control is maintained through 14 small hydrogen peroxide thrusters positioned around the Centaur.

A new astrionics system – mainly consisting of a Teledyne




Titan IIE/Centaur: principal components.

digital computer unit, and a Honeywell inertial reference unit – now controls many functions previously handled by separate systems. This new Centaur system handles navigation, guidance, propellent flow, telemetry, and vehicle performance. Much like a Saturn class vehicle the Centaur astrionics system can also perform pre-launch checks of itself and other vehicle systems. Commands to the Titan will now also be routed to the Centaur for relaying through the latter's guidance system to the Titan flight computer which will then forward the correct commands to the appropriate systems.

**Centaur Standard Shroud (CSS)**

To provide improved payload capacity a new Centaur Standard Shroud has been designed. A payload of almost 8.5 metres (28 ft.) in length can now be carried with the possibility of extending the shroud should a still larger capacity be required. The nose cap and conical sections are made from corrosion resistant steel and magnesium respectively whilst the cylindrical section which extends the length of the Centaur is corrugated aluminium.

Some 10 seconds after Titan stage 2 ignition, the shroud is severed by pyrotechnic charges horizontally below the payload and longitudinally along a sealed joint. To complete the separation, four compressed springs force the two halves of the shroud apart.

**Assembly and Launch Facilities**

Another innovation with the Titan/Centaur missions is the use of the Titan III launch complex at Cape Kennedy Air Force Station. This complex, which has not been used by any previous NASA missions, consists of three main areas built on man-made islands in the Banana River. After erection and mating of the Titan, Centaur and Centaur section of the shroud inside the Vertical Integration Building (VIB) the vehicle is transported to the Solid Motor Assembly Building (SMAB). The mobile transporter consists of a double-track locomotive system covering some 19.9 miles between the various facilities. Once in the SMAB the solid rocket motors are mated to the core stages before the vehicle is transferred to the pad at Launch Complex 41. A mobile service structure encloses the launch vehicle once it is on the pad and provides access to each of the stages. When it has been sealed inside the CSS, the payload is delivered to the Titan launch complex from the Spacecraft Assembly and Encapsulation Facility (SAEF) at KSC. Once at the pad the payload is mated to the Centaur to await launch.

For the duration of the Titan/Centaur missions Complex 41 will be under operational assignment to the Kennedy Space Center which of course is also responsible for prelaunch checkout and the launch itself.

**Titan/Centaur Missions**

The Titan/Centaur will have a very brief life. It can be economically used only to lift the heavier unmanned payloads into space and by the end of the decade will have been made redundant by the advent of the Space Shuttle. Apart from test flights – the first of which took place in February* – and unless further missions are approved the vehicle is at present only scheduled to make 6 operational flights. Two U.S.-West German Helios solar spacecraft will be launched – the first in September 1974, and the second 15 months later. In August 1975, two Viking spacecraft will be sent to Mars to continue the search for life both from orbit and from the surface of the Red Planet. Finally in August 1977, the mini-Grand Tour will begin when Titan/Centaur vehicles launch two Mariner spacecraft on fly-by missions to Jupiter and Saturn.

** Shortly after launch on 11 February the Titan/Centaur's maiden flight ended in failure when a malfunction occurred. The Range Safety Officer destroyed the vehicle over the Atlantic.*

# SATELLITE DIGEST — 72

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

*Continued from June issue, p. 219.*

| Name designation | Launch date lifetime and descent date | Shape and weight (kg) | Size (m) | Perigee height (km) | Apogee height (km) | Orbital inclination (deg.) | Nodal period (min) | Launch Centre, launch vehicle and payload/launch origin |
|---|---|---|---|---|---|---|---|---|
| Cosmos 628<br>1974-01A | 1974 Jan 17.42<br>1200 years | | | 958 | 1016 | 82.96 | 104.87 | Plesetsk<br><br>USSR/USSR |
| Skynet 2A<br>1974-02A | 1974 Jan 19.07<br>6 days<br>1974 Jan 25 | Cylinder<br>129 | 0.81 long<br>1.37 dia | 96 | 3406 | 37.60 | 121.48 | ETR<br>Delta<br>UK/USAF (1) |
| Cosmos 629<br>1974-03A | 1974 Jan 24.63<br>11.66 days (R)<br>1974 Feb 5.29 | Sphere-cylinder<br>4000? | 5 long?<br>2 dia? | 197 | 289 | 62.81 | 89.35 | Plesetsk<br><br>USSR/USSR |
| 1974-03D | 1974 Jan 24.63<br>16 days<br>1974 Feb 9 | Sphere? | 2 dia? | Orbit similar to 1974-03A | | | | Plesetsk<br><br>USSR/USSR (2) |
| Cosmos 630<br>1974-04A | 1974 Jan 30.46<br>13.7 days (R)<br>1974 Feb 13.2 | Sphere-cylinder<br>4000? | 5 long?<br>2 dia? | 203<br>179 | 346<br>342 | 72.84<br>72.85 | 90.02<br>89.74 | Plesetsk<br><br>USSR/USSR (3) |
| 1974-04F | 1974 Jan 30.46<br>17 days<br>1974 Feb 16 | Sphere? | 2 dia? | 162 | 273 | 72.82 | 88.87 | Plesetsk<br><br>USSR/USSR (4) |

*Supplementary notes:*

(1) First British built military communications satellite. Owing to a steering fault in the second stage of the launch vehicle 22 minutes after launch the satellite failed to reach its intended synchronous orbit. Radio contact was lost at the time of the malfunction but was re-established on 1974 Jan 24 and an attempt was made to stabilise the orbit. This manoeuvre was unsuccessful and decay occurred on the following day. The orbital data shown is for 1974 Jan 20.7.
(2) Ejected from 1974-03A during 1974 Feb 4.
(3) Orbital data at 1974 Jan 31.6 and 1974 Feb 5.4.
(4) Ejected from 1974-04A during 1974 Feb 12.

*Decays:*

Midas 2, 1960 Zeta 1 decayed 1974 Feb 7, lifetime 5007 days. (This is the longest completed lifetime to date).
Molniya-1H, 1969-35A decayed 1974 Jan 29, lifetime 2109 days.

*Amendments:*

1973-84A, add second orbit, perigee is 635 km, apogee is 39708 km, inclination is 62.79 degrees, period is 717.51 minutes.
1973-88D, add second capsule – a 60 kg octagonal cylinder 0.3 m long, 0.9 m diameter. Orbit as follows – perigee is 1419 km, apogee is 1458 km, inclination is 96.93 degrees, period is 114.64 min.
1973-108A, add second orbit: perigee is 910 km, apogee is 990 km, inclination is 64.91 degrees, period is 104.04 minutes, manoeuvre took place on or about 1974 Feb 11.

## SPACE REPORT

*Continued from page 275]*

### WEIGHTLESSNESS AND HEREDITY

Weightlessness may change heredity, according to Soviet geneticists who have been studying the influence of space flight on the cells of plants and animals. Director of the Institute of Genetics, Nikolai Dubinin, said that various plants, micro-organisms, insects and mice were under study. In one of the Institute's laboratories the first seeds that had been taken into space and sown 10 days before were of a weed of the mustard *(Cruciferae)* family. It was a regular "harvest" of the weed widely used by scientists of many countries to check their hypotheses. This method is popular because the plant passes through the whole cycle of its development in 30 days, so that more than 10 generations can be obtained in a year and it is possible to follow the hereditary changes in a comparatively short period.

During previous experiments the scientists obtained weeds of different colours – from green to brown – which is believed to be a result of weightlessness.

Academician Dubinin stressed that the first flight experiments had shown that weightlessness affects living organisms, in the first place the metabolism. It had been noted that the seeds taken to space were more susceptible to various chemical substances, to radiation and other factors of the environment which can cause hereditary changes.

Soviet scientists maintain that the more complex the organism is the greater are the changes that take place in it as a result of weightlessness. The evolution of life on Earth took place in the conditions of gravitation and many of the vital processes of organisms depend on gravity. Plants and animals clearly define their spatial posture. Every living creature on Earth has its special organ of orientation.

At the present stage of space flight the majority of physiological processes are reversible. However, the geneticists believe that only a long stay of plants and animals in space will show whether this can cause more serious changes.

# SOCIETY NEWS

### Space Law Lecture

The Space Study Meeting on February 13th featured a lecture by Cyril Horsford on the Principles of Space Law. He began by tracing the early beginnings of international interest in controlling space activities, starting with the writings of international lawyers and the setting up of the UN Committee on Outer Space in 1958. The main topics of space law included the doctrine of freedom in outer space, the prohibition on sovereignty over the Moon and the planets, control of space broadcasting, and liability for damage caused by space operations.

The three U.N. Space Treaties now in operation were described i.e. on General Principles in 1967, on Rescue of Astronauts in 1968, and on Liability for Damage in 1972.

As a former Director of the International Institute of Space Law, which meets every year at the time of the I.A.F. Congress, Mr. Horsford was able to give some of the latest thinking among lawyers on current and future space law problems, such as the space shuttle and earth resources satellites besides potential dangers from unregulated direct broadcasting by satellite.

### 25th Anniversary of the Western Branch

On 13th September 1952, five years before Sputnik 1, the then Bristol Group of the BIS held its first meeting in the Folk House, which used to be adjacent to Bristol Central Library.

Application for status as the Western Branch was begun on 7th March 1953 and provisional Status granted on 23rd January 1954.

A forum on 'The Venusian Probe' was started as the first technical study to be carried out by the Group and was Chaired by Mr. F. A. Smith.

On 24th April 1954 the provisional Western Branch staged its first public exhibition of rockets and space travel, followed by a Celebration Dinner in the Grand Hotel on 2nd October 1954 to mark the Society's 21st Anniversary. Guests of Honour were Dr. Black, of Bristol University, and Patrick Moore and Len Carter, representing the Council.

Full Branch Status was granted in Feb. 1955, the Venus Probe paper was sent for publication in JBIS in Dec. 1957 and the Bristol Moonwatch Team, under the leadership of Mr. A. F. Collins, formed during June 1958.

In Feb. 1959 an exhibition was held at the Folk House to mark the IGY. On 6th December 1962, the 10th Anniversary of the founding of the Branch was marked by a Dinner in the Royal Hotel. Guests of Honour were the Lord Mayor of Bristol and the late Sir Roy Fedden.

In May 1966 the Branch was visited by the NASA Spacemobile Team, then being operated on a 4-month tour by HQ.

The Main Meeting in April 1969, on the theme of 'Materials in Space Technology', also allowed those taking part to see the maiden flight of Concorde 002 at Filton

In Feb. 1971 a Moonrock sample was displayed by Dr. Eglinton during his lecture to the Branch.

The 21st Anniversary of the Branch was marked by a lecture in the University of Bristol, on 18th October 1973, and – by a happy co-incidence – marking also the grant of the Royal Charter to the City of Bristol 600 years ago. The Guest Speaker, returning to the Branch after a ten year lapse, was Arthur C. Clarke, who spoke on 'Man's Future in the Universe'.

### BIS Starship Study

About 60 people attended the meeting in London on 29th April 1974, to hear a Report on progress with the BIS starship study, Project Daedalus.

Alan Bond, the study organiser, introduced the report by giving details of the propulsion system design process, resulting in a possible engine based on a nuclear-pulse rocket: Anthony Martin described interest in the possible planetary system around Barnard's Star, and other targets to which a probe might be sent: James Strong discussed work on the navigation aspects of the mission, detailing possible stars to be used for tracking during the flight: Rodney Buckland described payload ideas, and introduced a method of weighting the value of possible instruments. Finally, Anthony Lawton discussed some of the communications problems connected with data relay over interstellar distances, and during different phases of the mission.

A fuller report of the meeting will appear in *Spaceflight*, later, with more details of the progress to date, and indicate ways in which those who wish to contribute to the study can help.

## 80,000-YEAR VISITOR OBSERVED

*Concluded from page 251]*

(passing over Belfast), the Irish Sea, Isle of Man (with the lights of Douglas promenade clearly visible), the Wirral Peninsula (with a cargo ship passing up the river Mersey towards Liverpool docks) and, finally, over Manchester suburbs to arrive back at the airport domestic pier some 2½ hours from its take-off. The general feeling among the 75 passengers was that the venture had been well worth the time, effort and expense and that a unique opportunity to view an 80,000 year celestial visitor had not been in vain.

*Members will be interested to know that Professor A. J. Meadows will speak on "Studies of Comets", at the Society meeting on 4 November 1974 to be held at the Royal Society of Arts, John Adam Street, Strand, London, WC2.*

## STAR TREKKING : WHOSE SUN ARE YOU?

*Concluded from page 257]*

view for 'Sun Spot' studies, a complete change within a normal Earth week!

Contrast this with *Betelgeuse* 10000 times as bright as the Sun, but a similar surface temperature to Barnard's star. The apparent diameter will still be 6 times that of the Sun, but the orbit is now 9,300 million miles (100 AU) from the parent, and the 'Year' is over 60 years – in fact off the scale. Yet again contrast with (say) *Deneb* – an A type star. The orbit would be 1300 million miles (140 AU) and the 'Year' would be a century – and yet the apparent diameter would be just over one third that of the Sun.

These are extreme examples of what the 'Trek Chart' can show. I fully realise that it is very unlikely that Earth-like planets orbit either *Betelgeuse* or *Barnard's Star*, but if we can imagine that they do, then we can portray the conditions and colours for such planets, and it is the artist's prerogative to use imagination and licence.